INVESTIGATION IN TO THE STATUS OF MAINTENANCE MANAGEMENT SYSTEM OF FARM MACHINERY: A CASE OF WONJI-SHOA SUGAR ESTATE

By:

Kebede Lemi Geno

DEPARTMENT OF MECHANICAL SYSTEMS AND VEHICLE ENGINEERING
SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

Thesis

A thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agricultural Machinery Engineering

Office of Graduate Studies

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

Adama, Ethiopia

January, 2019

INVESTIGATION IN TO THE STATUS OF MAINTENANCE MANAGEMENT SYSTEM OF FARM MACHINERY: A CASE OF WONJI-SHOA SUGAR ESTATE

By:

Kebede Lemi Geno

Advisor: Dr. Amana Wako

DEPARTEMENT OF MECHANICAL SYSTEM AND VEHICLE ENGINEERING

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

Thesis

A Thesis Submitted In Partial Fulfillment of the Requirements for the Degree of Master of Science in Agricultural Machinery Engineering

Office of Graduate Studies

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

Adama, Ethiopia

January, 2019

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the project entitled "**Investigation in to the Status of Maintenance Management System of Farm Machinery; A Case Study on Wonji-Shoa Sugar Estate**" in partial fulfillment of the requirement for the award of the degree of Masters of Science in Agricultural Machinery Engineering of an authentic record of my own work carried out from February, 2017 to December, 2018 under the supervision of Dr. Amana Wako Department of Mechanical system and Vehicle Engineering, Adama science and Technology University, Ethiopia. The matter embodied in this project has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this project have been duly acknowledged.

Kebede Lemi Geno _____ _____

Signature Date

ADVISOR DECLEARTION

This is to certify that the above statement made by the candidate is correct to the best of my Knowledge and belief. This project has been submitted for examination with my approval.

Dr. Amana Wako _____ _____

Advisor Signature Date

APPROVAL SHEET OF BOARD OF EXAMINERS

We, the undersigned, members of the board of examiners of the final open defense by MSc student Kebede Lemi Geno have read and evaluated his thesis entitled "Investigation in to the status of maintenance management system of farm machinery: A case study on Woji-Shoa Sugar Estate'' and examined the candidate. Therefore, this is to certify that the thesis has been accepted in partial fulfilment of the requirement for the degree of Master of Science in Agricultural Machinery Engineering.

Approved By Board of Examiners

Chairman, Department Graduate Committee	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date
Advisor	Signature	Date

AKNOWLEDGEMENT

First and foremost, I want to express my enormous thanks to the almighty God for his continuous and priceless help and permission to finish my graduate studies successfully and Adama Science and Technology University (ASTU) for giving me chance to pursue my postgraduate studies.

I would like to express my sincere and special thanks to my advisors Dr. Amana Wako for the continuous support and guidance he made to me in doing this thesis and their most valuable contribution in reading and commenting the thesis work.

I am also thankful to all the Wonji-Shao Sugar Factory maintenance management unit and workers for their positive co-operation and support in the data collection for this thesis work. Special thanks shall also go to Mr. Tsegaye Mengistu (Land Preparation and Cultivation Team Head), Mr. Aragawe Sisay Field Equipment and Service Department (FESD) planning office, Mr. Ephrem Seifu (FESD heavy duty section head), Mr. Aklilu Haile (FESD heavy duty section supervisor) and Mr. Abebe Wondimu (FESD wheel tractor section supervisor) in giving me valuable information at the time of data collection.

Last but not least, my thanks go to my parents, relatives and friends who helped me in one way or another way during the study. I am strongly thankful to my brothers Belay Lemmi for his continuous support throughout my education from the very beginning.

TABLE CONTENTS

CONTENT **PAGE**

LIST OF TABLE

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

LIST OF APPENDIXES

APPENDIXE **PAGE**

ACRONYMS

ANOVE	Analysis of Variance
ARM	Accumulated Repair and Maintenance Cost
ASAE	American Society of Agricultural Engineers
CO	Complete Overall
CR	Capital Recovery
CT	Crawler Tractor
CMMS	Computerized Maintenance Management System
ECM	Electronic Control Module
FAO	Food and Agricultural Organization
FESD	Field Equipment and Service Department
GAIA	Global Agricultural Information Network
GOE	Government of Ethiopia
HVA	Hangler Vonder Amsterdam
LPCT	Land Preparation and Cultivation Team
LP	Liquid Petroleum
MMS	Maintenance Management System
PM	Preventive Maintenance
RCM	Reliability Center Maintenance
RV	Remaining Value
TAR	Total Accumulated Repair
TIH	Tax Insurance and Housing
WT	Wheel Tractor
WSSF	Wonji-Shoa Sugar Factory

ABSTRACT

Wonji-Shoa sugar Estate is accommodates a large number of agricultural machineries and provides maintenance services for different types of machineries in its garage. In this maintenance section the machineries are failed frequently, shorter life expectancy, greater chance of inspection failure and repeated breakdowns is the main problems. This research work examined the status of the existing maintenance management system and seek to bring effective machinery maintenance. In order to ensure that the machinery availability in good condition, serviceable and safe to be operated in producing quality products by taking the Estate as a case study. To show this, data were collected through, questionnaires, interview, direct observations and review of existing secondary data on the maintenance management system. The parameters evaluated were maintenance planning and implementation, machinery status, manpower characteristics, training program and operating cost of machinery. The data were tabulated and analyzed using descriptive statistics and frequency tables in Microsoft excel 2013 computer software. The major finding of the study indicated that the status of agricultural machinery maintenance management practice in the sugar estate was inefficient and maintenance cost was also significantly high. The fact that proper attention was not given by the factory's management has worsened the problem. The study recommended that the maintenance management should give proper attention to service and maintenance department.

Key words: - Management, implementation, Evolution of maintenance, availability.

CHAPTER ONE

1. INTRODUCTION

The world today is heavily dependent on technology and automation. As technology advances we can do more with machines but we also become more dependent on them. In many industries the equipment required to produce goods and services was expensive to own, operate, maintain and faults even in a single piece of equipment can halt an entire production. In addition to direct production losses, the downtime caused by an equipment failure may damage company reputation and in some cases, lead to fines and penalties. These things make maintaining the equipment properly a key activity for companies and in some industries companies spend up to 50% of their operational costs on maintenance. In today's competitive environment understanding the total cost of maintenance and optimizing these costs has a big impact on company profitability (Campbell, 2016).

The sugarcane sector is a key economic activity in Ethiopia due to its productivity and technology applied in agricultural areas. Economically one of the most important with prospects for expansion of the sector. In recent years, the Government of Ethiopia (GOE) has made heavy investments in the country's sugar sector, among which were the construction of new sugar processing factories, the revitalization of older factories and the expansion of land under sugar cultivation. With these investments, the GOE envisions the country becoming one of the world's ten largest sugar producers by 2023 as reported by Global Agricultural Information Network (GAIN, 2015). To achieve this, the maintenance management system must be effective and efficiently managed in order to increase machinery work effectiveness and availability.

Currently agricultural machinery is one of the most important power sources in agriculture and it's effect on agriculture is considerable (Gifford et al., 1980). The use of modern technology during last decades resulted in rapid growth of farm production. The Ethiopian sugar industry is the largest agro industry of the country and occupies an important position in the country's economy. One possibility of improving the profitability of the sugarcane production system is the use of agricultural machinery in all activities of sugarcane production.

1.1. Background and Justification

Commercial sugarcane plantation was started in Ethiopia in 1951 by Dutch company Hangler Vondr Amsterdam (HVA) which was granted a concession of 5000 hectors for establishing a sugar estate and a factory in the Wonji plain which lied downstream of Awash River. In 1954, Wonji sugar factory had the first milling season and produce 6,000 tons of white sugar (first bag of Ethiopian sugar). In order to meet the rising demand of sugar in the local market another 1600 hectors of land was granted to the HVA Company by the Ethiopian government thus totaling 6600 hectors. During that time, even though the exact data are not found, the factory began its agricultural activity with few machineries and little man power wonji-shoa sugare factory (WSSF), (2017)

However, at this time the factories have so many agricultural machineries which are used to cultivate, farming, applying fertilizer, harvesting cane, and transporting of cane from field. Therefore, maintenance of management has a crucial role for successful agricultural production. It is guaranteeing the safety of operations, availability of machineries and related equipment for farm operation. An intensive agricultural production system, large amounts of capital is invested for the acquisition, operation and maintenance of agricultural machinery. Hence, the execution of operations by one or many cooperating machineries needs to be carefully planned in order to achieve maximum efficiency.

The field equipment and service department (FESD) was very old which served for about 55 years with old agricultural machinery maintenance management system. It has three main Maintenance and repair sections which are Heavy equipment section, Wheel tractor section and Estate car section. The equipment failures were rectified through breakdown maintenance action while preventive maintenance was used to reduce the occurrence of failure. The frequently failure of machineries can cause serious economic and social consequences. Therefore, agricultural machinery maintenance management should be done so as to achieve the objectives of the organization by making the rational between breakdown and preventive maintenance and optimizing higher availability of machineries through reducing down time. In this paper the study were thoroughly investigated on the variations in repair and maintenance costs among the machineries, the factors that cause this variation and the magnitude of this variation on agricultural machinery maintenance condition.

1.2. Statement of the Problems

Wonji -Shoa sugar estate deals with different types of machineries, wheel and crawler tractors with different farming implements. The shorter life expectancy for machinery/equipment, greater chance of inspection failure, increased downtime for equipment, repeated issues and breakdowns was the main problems. Improper maintenance planning and implementation, inefficient number of skilled manpower, training program and lack of spare parts in the stock and failure of modification work for the spare parts is the other problems. This means that there is no clear link between maintenance activities and company's strategic goals. These making it difficult to maintenance quality obtained.

1.3. Objectives

Taking the above problems into consideration, the thesis work focus on the accomplishment of the following objectives.

1.3.1. General Objective

Investigate the status of maintenance management system of farm machinery, in order to improve productivity in Wonji-Shoa sugar estate

1.3.2. Specific Objective

- To assess and evaluate the current maintenance management practices used by the maintenance management system in the sugar estate.
- Reducing cost of using farm machinery by establishing effective maintenance management.

1.4. Significance of the Study

Today, in the race of generating more earnings and to remain competitive among rival, the decision-making was important and should be optimize. The productivity of industries is highly dependent on their machineries and equipment. Machinery and equipment productivity can be improved by managing the farm machineries maintenance in optimum process condition, good maintenance, reducing idle time and making more effective use of available machineries and its capacity.

Proper maintenance management for Agricultural machinery is very important due to the high investment involved in the purchase and operating cost of the machinery. Identify causes of the machinery problems and thoroughly analyze failures in farm machinery maintenance management system that lowers productivity.

As a result of effective and efficient maintenance management, it was possible to prolong the physical, technical and economic service time of agricultural machineries/equipment. The main significance of the study was to bring and implement effective machinery maintenance management systems to ensure that the machinery was in good condition, serviceable and safe to be operated in producing quality products. If the machineries could not be properly handled and maintained cane couldn't be cultivated, planted, harvested and supplied to the factory as a row product then cane sugar production could be in question.

1.5. Scope of the Study

The scope of the study has been limited to examine the maintenance management through the common maintenance practice, planning and implementation, training program and skill of maintenance personnel at FESD, the operating cost of different tractor makes and models used. That where assumed as the most representative parameters to measure the current status of maintenance management system which has direct impact on production process in wonji-shoa sugar estate are evaluated during the seasons 2015/16 and 2017/18.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definition of Maintenance

A concise translation of the word maintenance from Oxford dictionary was the "activities done to keep equipment and machine in its existing state, preserve, and ensure it to continue operating in good condition while at the same time protecting it from potential damage." Maintenance was defined as the combination of all technical and administrative actions including supervisory actions, intended to retain an item in a state where it can perform a required function (Seeley, 1976). It was also defined as the restoring of an item to it is original condition of working order. This can be achieved by repair, replacement of parts or total replacement of the item.

2.2. Types of Maintenance Strategy

Maintenance strategy is a long term plan covering all aspects of maintenance management which sets direction for maintenance. It describes the systems and procedures to be used to plan and manage maintenance work. It also specifies the types of maintenance to be carried out. Strategic maintenance planning is a structured process undertaken to ascertain the immediate, medium and annual maintenance requirements of the machinery. Strategic maintenance planning involves a review and analysis of the organization's maintenance system, corporate and service delivery objectives and the machinery maintenance environment. Maintenance is seen as a strategic functional area, which has the potential to reduce the overall cost while improving the quality, productivity or availability and reliability (Dhanpat, 2004). Maintenance strategy is classified generally into planned and unplanned maintenance as in the figure 2.1.

A, Planned Maintenance

Preventive maintenance: -This is a planned maintenance activity that was designed to improve equipment life and avoid any unplanned maintenance activity. It includes the lubrication program plus routine inspection, cleaning and adjustments. These service steps take care of small problems before they cause equipment outage. With this maintenance, equipment service levels begin to enter the acceptable range for most operations (Dinesh and Bikash, 2005). Planned preventive maintenance is work organized and carried out with forethought, control and use of records to a predetermined plan.

B, Unplanned Maintenance

Breakdown maintenance: - This was just as what its name implies, it work resulting from unseen breakdown or damage due to external causes. The equipment is run until it breaks down or its performance is unacceptable. It was also called Run-to-failure maintenance. There was no preventive maintenance; the technicians work only on equipment that is malfunctioning. This is the most expensive way to do maintenance. Equipment service level was generally below acceptable levels with product quality usually impacted. Equipment has never been offline for maintenance (Dhillon, 2002).

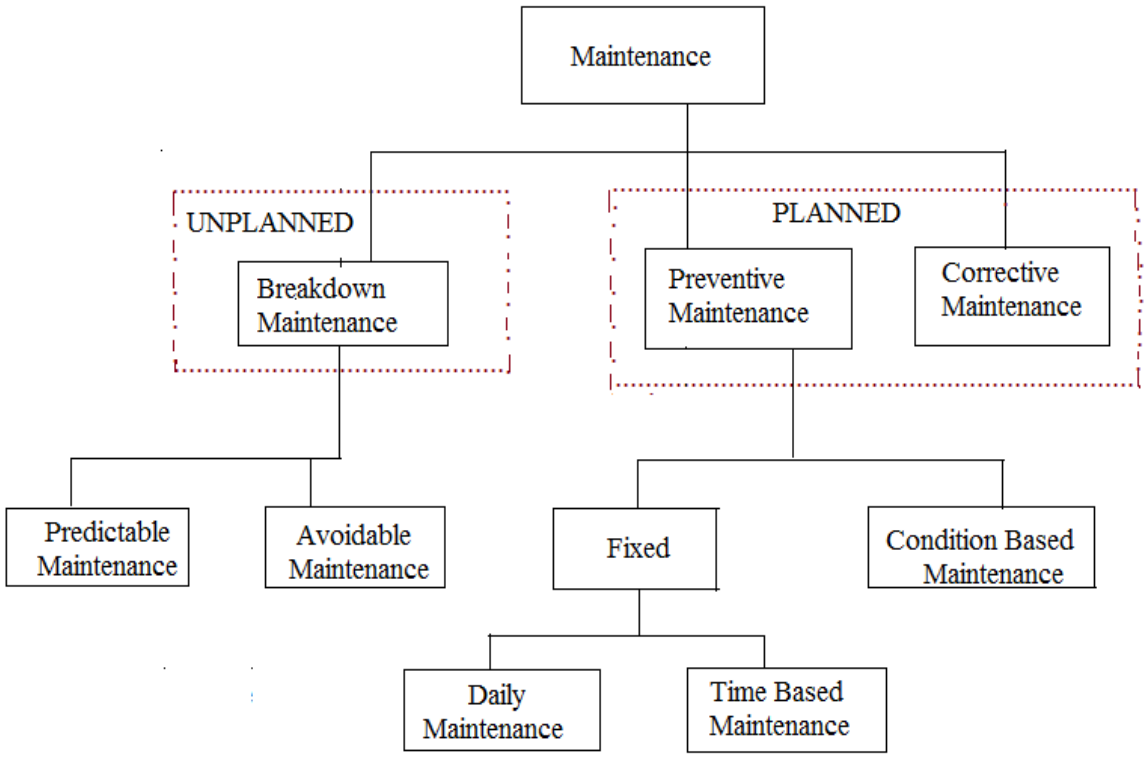


Figure 2. 1.Types of Maintenance

2.3. Maintenance Management System

Maintenance management is an orderly and systematic approach to planning, organizing, monitoring and evaluating maintenance activities and their costs. It also refers to the application of the appropriate, staffing, program implementation and control methods to the maintenance activity. (Tomlinson, 1993), Often, decision-making is concerned with optimal allocation of resources to various activities with the final aim of lowering the operating costs by increasing reliability, availability, quality and safety.

Maintenance is seen as a strategic functional area, which has the potential to reduce the overall cost while improving the quality, productivity, availability and reliability (Dhanpat 2004). A good maintenance management system coupled with knowledgeable and capable maintenance staff can prevent breakdown and safety problems.

2.4. Historical Perception of Maintenance Management

Maintenance has evolved over centuries and has played significant role for growth of organizations. Maintenance history was differentiated by three generations, the development of maintenance considered from being "necessary evil" to "profit contributor".

2.4.1. The First Generation of Maintenance Management

The first generation of maintenance management was before and up to the second world war with the expectation of ''Fix equipment when it breaks" with the views on equipment failure as all equipment ''wears out''. The maintenance technicians were working with the basics of maintenance and the fundamental of repair skill of the equipment. The first Generation of maintenance management was "Reactive Maintenance". It was considered as "run the equipment till it breaks" maintenance methodology. Prior to the early 1900's maintenance was considered a necessary evil (Tsang, 2002).

The maintenance team doesn't do any actions or efforts to maintain the equipment as the original manufacturers were intended to insure design life was related. Minimum incidents of failures can occur in dealing with new equipment. If our maintenance activities were purely reactive then capital cost won't incur until something breaks. Thus reactive maintenance can be viewed as a double-edged sword. Reactive maintenance period can be viewed as money saving period as no maintenance cost or capital cost are incurred.

But in reality it spending more cost as not taking any proactive measures, the cost can be reduced if the problem is detected earlier instead of waiting for the equipment to break. And shortening the life of the equipment without proper maintenance program. The labour costs will be higher than the normal as it requires expensive repairs like replacement of primary device of the equipment. This may also incur maintenance overtime cost and require a large material inventory of repair parts. This could minimize under a different maintenance strategy.

2.4.2. The Second Generation of Maintenance Management

After Second World War and with technological advances, maintenance was considered a support function. All equipment complies with the "Bath-tub" curve. Maintenance techniques followed are scheduled overhauls. System for planning and controlling work. The second generation of maintenance management was "Preventive maintenance". Preservative maintenance as a means to increase the reliability of their vessels. The expectation of this type of maintenance was higher equipment availability, longer equipment life and lower maintenance costs. In addition to an increase in reliability. Cost were saved over that of a program just using reactive maintenance. Preventive maintenance was better and has more advantages than reactive program (Dunn, 2003). There was no alternative for avoiding failure and the general attitude was "It costs what it costs". Through preventive maintenance extend the life of the equipment and can run the equipment more efficiently. Preventive maintenance like lubrication, filter change etc. enables to reduce the number of failures which in turn result in capital cost savings.

2.4.3. The Third Generation of Maintenance Management

The third generation of maintenance management was after 1970s with the expectations of higher equipment availability, higher equipment reliability, greater safety, better product quality, longer equipment life and greater cost effectiveness (Dunn, 2003). The maintenance technique followed were condition monitoring, design for maintainability and reliability, hazard studies, failure modes and effective analysis, expert system, team work and empowerment. The third generation of maintenance management was "Reliability Maintenance". Today maintenance was considered an integral part of business process and it's perceived as creating additional value.

- Equipment reliability: the ability of an item to perform the function under static condition for stated period of time. With this regard, during designing, manufacturing and assembling activities, care must be taken in order to maintain high reliability of operation at accepted added cost.
- Equipment availability: According to Demise et al., (2002) availability performance was a measurement of maintenance efficiency and can be defined as measurement of performance of equipment in the terms of ability to operate without problem in despite of disturbance and limitation of maintenance resources.

- Greater safety: was an important expectation of maintenance particularly in the sense of maintenance ensuring that equipment can be operated safely.

- Risk management: an increasing focus with in organizations on identifying and managing potential high consequence, low probability events, particularly in those origination operating in hazardous industries.

2.5. Maintenance Management Process

A Maintenance management process assists organizations in establishing a framework for maintenance works. It`s objective is to achieve consistency in planning, implementation and reporting of machinery maintenance. It must be emphasized that the establishment of condition standards is fundamental to the maintenance management process as seen in the figure 2.2 shown below

The development of condition standards provides a statement of the desired condition standard to which assets should be maintained to enable an organization service delivery to be achieved effectively (Parida et al., 2006). As such maintenance management supports the effectiveness operation process by eliminating and reducing the frequency and severity of equipment failure.

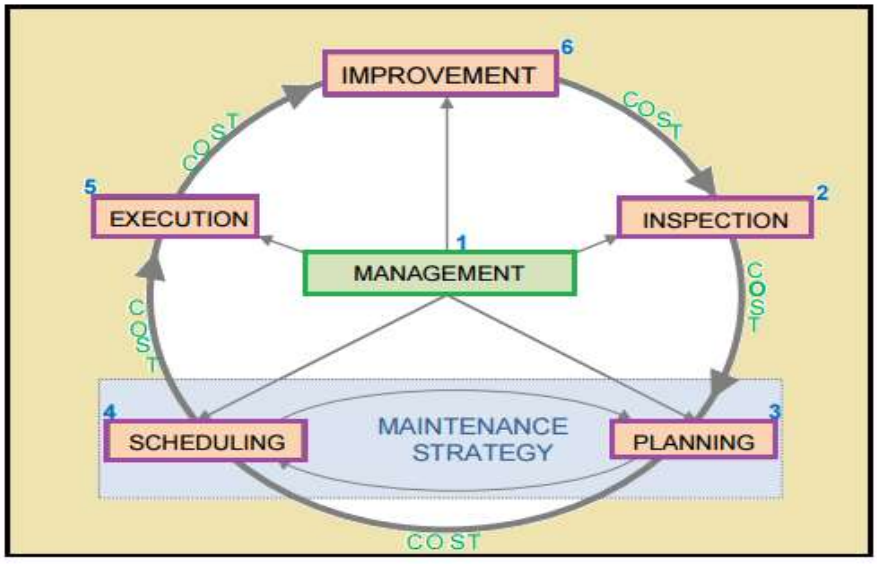


Figure 2. 2.Fundamental Maintenance Management, Lee (1987**)**

The function of managing the maintenance process is maintenance management. The maintenance process starts with the maintenance objectives and strategy which are derived from corporate vision goal and objectives based expectations. Based on the maintenance objectives, maintenance policy, organization, resources and capabilities a maintenance program needs to be developed. The program was broken down into maintenance tasks.

The execution of maintenance tasks was under taken at specified times and locations as per the maintenance plan. Management must understand the importance of maintenance and match the plan to the vision, goals and objectives of the organization. Maintenance policy refers to a formalized set of rules and guidelines to achieve good maintenance processes and practices. It has also been described as a written document that provides a management frame work to ensure machinery assets are maintained appropriately to support the organization's strategic objectives.

It was realized that maintenance activities may not achieve the desired outcomes without a defined maintenance policy. Lee (1987**),** defines maintenance policy as the ground rules for allocation of resources between the alternative types of maintenance actions that were available to management. Implementing a good maintenance policy prevents system failures and leads to high productivity. Agricultural machinery downtime can be reduced by the following means: i.e. speedy fault detection.

Fault should be detected before it becomes enough to affect performance of machinery. Speedy faulty diagnosis; in this case the time spent in faulty diagnosis can be reduced. The other one is speedy repair which includes time required for faulty detection and diagnosis, removal of assembly, striping, adjustment, assembly and then finally trial (check) test. For speedy repair it was essential to use latest tool, immediate decision should be there to adjust, recondition or repair a particular part of machinery.

2.6. Machinery Maintenance and Spare Part Management

One of the main components of the properly organized process of the machine and equipment supervision in any enterprise is the choice and the use of a proper management strategy. Management of farm machinery is one of the important branches of farm management.

Deciding considering replacement time of farm machinery noted to conditions of their economic and technological is one of the considered aims in management of farm machinery. How and when equipment is replaced can mean a difference of thousands of dollars in annual production costs Johnson, (1979).

Deciding for replacing old machinery by new machinery was performed based on its economic life. Economic life, named as optimum life, has a direct relation with repair and maintenance costs. Costs of owning and operating of farm machinery represent 35 to 50% of the costs of agricultural production according to Journal of Agricultural Technology, (2010). To bring effectiveness, the maintenance manager has to be well versed in key performance measurement. Measure of productivity, quality and cost on time delivery, and quality of working life, innovation and profitability are regularly used to assess the performance of the system and that of subsystem within the maintenance function.

Spare Part Management, all organizations require some level of spare parts management to ensure the right parts will be available when needed. Reactive organizations typically find themselves carrying a large quantity of inventory because they cannot predict when the parts will be needed. This ties up working capital and results in excessive carrying costs. Organizations that take a proactive approach to reliability place a high value in knowing the condition of their assets. The need for parts was much more predictable. There are fewer "surprises"; more parts can be purchased on a just-in-time basis. Since the volume of inventory required is based to a large degree on usage, the fewer parts we use, the fewer we need to keep on hand (Anthony, 2006).

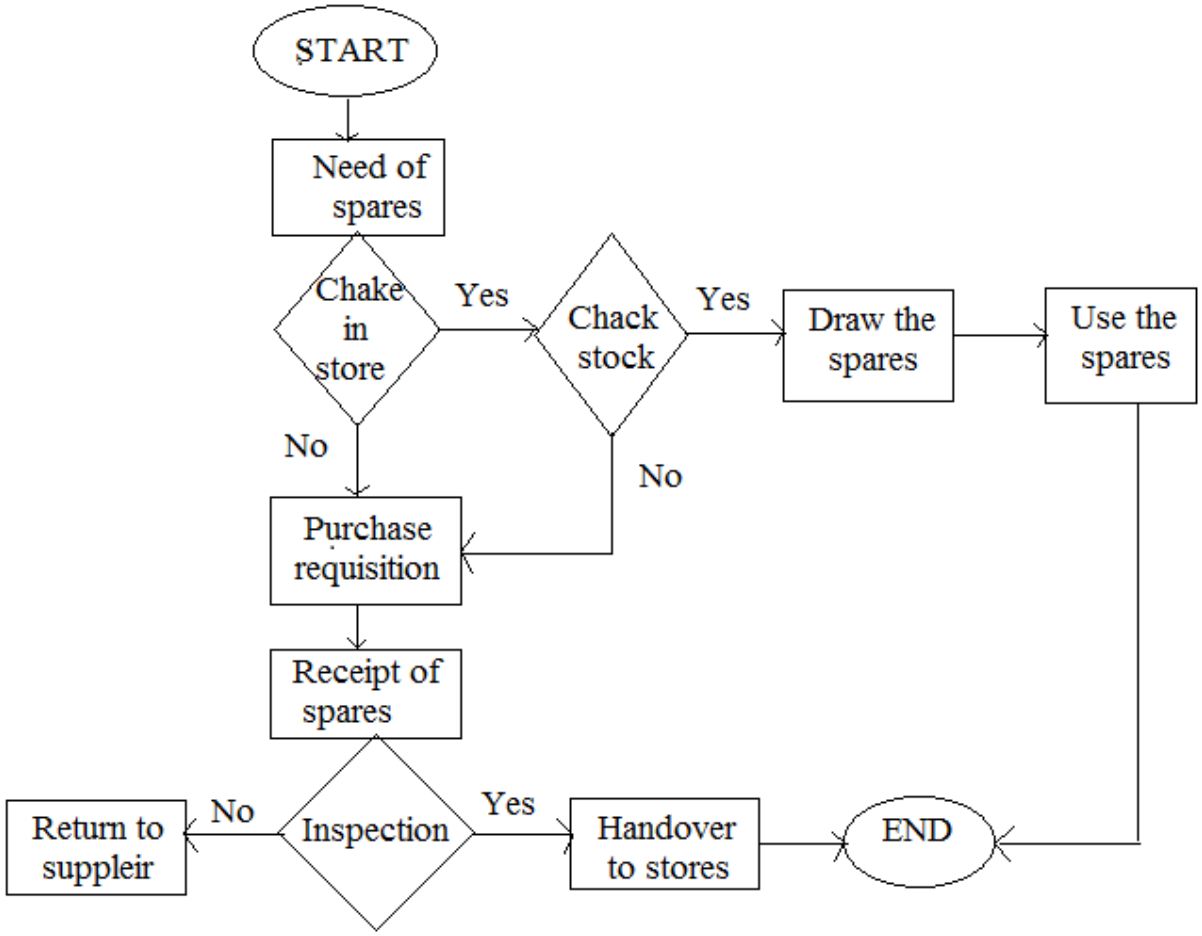


Figure 2. 3.Spare Parts Management Process Flow Diagram

2.7. Machinery Maintenance Standard

Maintenance standards establish the acceptable condition of machine, facilities, utilities, systems and determine the level of maintenance allowed to maintain the standard. The standards are determined by the designed function, type of machinery, age, purpose, present and future requirements and replacement cost. Knowledge and application of the standards permit decisions to be made concerning the extent, frequency and necessity of inspections and maintenance of facilities, systems and equipment. They also provide a source of comparison between the actual condition and the acceptable standard for a particular unit (Dhanpat, 2004). Machinery/equipment standards include inspection and repairing standard

Inspection standard: these are standards for inspecting equipment, in other ward technique for measuring of otherwise determining the extent of deterioration.

Servicing standards: these standards specify how servicing and routine maintenance done with hand tool will be carried out. They include method and guide line for different type of servicing such as cleaning, lubrication, adjustment and part replacement.

Repair standards: repair standards specify condition and method of repair work.

Maintenance work standards: maintenance standards prepared for frequently performed work (Oakland, 1993).

- Equipment design standards or simply equipment standard
- Equipment performance standard/ equipment specification.
- Equipment material procurement standards.
- Equipment materials inspection standards.
- Test run and acceptable standards.

2.8. Economic Benefits of Standardization

The obejective of standardes was to bring uniformity and consistency in the principles and methods of determining the repairs and maintenance cost with reasonable accuracy. Some of the main economic benefits gained through establishing and implementing standardization system are;

- **Redaction in the investment of equipment and spare parts**

When equipment and vehicles were closed related by good standardization, it was possible to reduce investment costs. Investment cost reduction was obtained by holding lower stock values of spare parts that can be utilized to minimize down time cost. Standardization helps to reduce the paper work to order and purchase parts. Due to fewer values and of stored parts and subassemblies while effective standardization system was developed and carrying cost was undoubtedly reduced.

- **Lower maintenance cost**

When owned equipment/vehicles were closely related, the technician will maintain similar equipment and vehicles and became specialized in repairs as well as in trouble shooting. Thus, standardization aid to lower training cost than when equipment and vehicles varies in size. Make and model.

- **Lower operating cost**

When equipment and vehicles were closely related in size, make and model, it was easier to replace operators in case of illness, absence or retirement. Thus, effective and efficient standardization resulted in lower training of operators and overhead cost. But due to lack of maintenance management system WSSF did not use such advantages. While, a state farm has several verities of vehicles, standardizing the existing system will benefit now and in the future. Further it remedies some of the problems in maintenance management system. Hence, it was recommended that WSSSF should develop good standardization system based on their:

Application,

Function,

Make, size and model

2.9. Maintenance Planning and Scheduling

Planning and scheduling functions are the key deliverables of the maintenance management role. In some larger organizations, planning and scheduling were split, allowing more adequate resources for each role. The difference between planning and scheduling is that, planning is the job of looking into the future and anticipating the resource needs of a project or repair, but scheduling is the execution step of the planning process (Al-Turki, 2011)

1, Planning

Planning (How to do the job) is the determination of all necessary elements required to perform a task in advance of performing the job. It is the heart of good inspection and preventive maintenance. Good planning ensures proactive maintenance strategies to provide effective maintenance to the equipment. All maintenance work should be planned so that the quality and cost effectiveness of the work is assured. To put it simply, planning was to provide an accurate description of what was needed, For example. Manpower, tools, materials, and equipment, at the proper time before the job was started as in the figure 2.4.

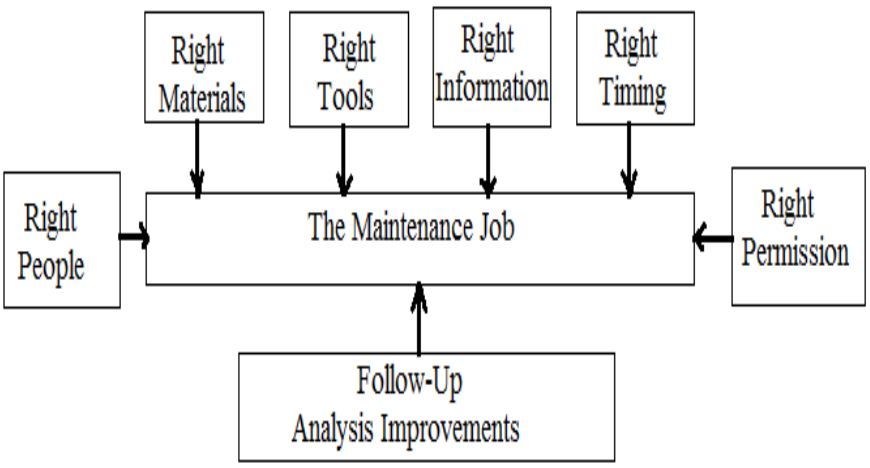


Figure 2. 4.The Role of Planner's

This lack of emphasis causes much of the criticism labeled at maintenance department for being too costly or unresponsive to the organization's needs .Good planning of maintenance function should include (Herbaty, 1983).

- A general plan on the distribution of labor throughout the various departments under "normal" operating conditions.

- Detailed planning and scheduling of major events taking place during the year such as major overhauls or rebuilds, large construction jobs, major preventive maintenance tasks and vacations of maintenance workforce. Preventive maintenance tasks should include routine maintenance, preventive maintenance, general repairs and emergency maintenance.

- Required spare parts, tools and other supply From the standpoint of the business organization, the planning can be divided into three basic levels, namely long range planning, short range planning and daily job planning

A, Long Range Planning

Long range planning is to provide plans for future activities and improvements to the maintenance function and can be for a period of five years or more. The primary purpose of long range planning is to keep the maintenance objectives, policies, and procedures updated so as to support the objectives of the company.

B, Short Range Planning

Short range planning is concerned with the annual plan of operation of the maintenance function. This plan will specify how the maintenance workforce will operate during the coming year and will also provide detailed plans for major rebuilds or overhauls, upgrading, construction jobs, vacation planning, and also any changes to the production plan. Short-range plans should include preventive maintenance of periodic inspection, Common PM Actions, shutdown planning, general repairs, Daily Job Planning and non-destructive testing which is commonly known as predictive maintenance.

It will also ensure that maintenance actions are on schedule and that the execution was carried out effectively and productively. Planning of the maintenance function must be performed throughout the three levels of planning namely, long range, short range and daily planning. The various actions in each level of planning will require decision making and consensus among all involved before implementation. This is to achieve overall commitment and team spirit even during times of trouble.

2, Scheduling

Scheduling (when to do the job) is an important tool for ensuring high labor productivity and the orderly accomplishment of maintenance tasks and actions. It is the action to arrange for the availability of all the planned elements prior to the job execution. Two-way communication between the operation and the maintenance department is critical so as to ensure that any maintenance plans are made known to the operation department in advance. It is equally important to ensure that the planned elements or resources are properly scheduled so as to perform the job adequately (Herbaty, 1983).

To ensure that all the planning effort is efficiently implemented, all the various maintenance actions and tasks such as general repairs and overhauls, preventive maintenance, lubrication's, and routine maintenance must be all scheduled. Scheduling of maintenance work can be divided into two main types, namely long range scheduling and short range scheduling.

A, Long Range Scheduling

Long range maintenance scheduling or master scheduling, is sometimes referred to as working ahead of the schedule or forecasting. Forecasting is often employed in conjunction with planning to help identify the desirable implementation dates, which often can be as long as ten weeks ahead. This lead-time ensure that the required personnel are made aware of the proposed timing of the job and also allows for sufficient time for the planning actions to be performed on time (Niebel, 1994).

B, Short Range Schedule

Short-range schedule can be divided into weekly or daily schedules and is constructed from the long-range schedules to provide for the orderly introduction of emergency work as it occurs and the routine maintenance work. Short-range schedule permits the comparison of labor and material resources with work requirements. According to Niebel, (1994), about 85% of the weekly schedule is based on general repairs and overhauls, preventive and routine maintenance work while the remaining 15% is held open for emergency work. However, if emergency work is occurring regularly and utilizing more than 15% of the work force an effort should be made to determine the causes.

C, Weekly Scheduling

In the planning of a weekly schedule, it is often useful to employ a two-week schedule (Niebel, 1994). The reason is that the planning function will not only provide for the work to be completed in the current week, but also for the subsequent week. In this way, there will always be a backlog of two weeks of work orders scheduled according to the priority. In the event of no emergency work being requested and the weekly schedule is running ahead of time, advance planned work can be brought forward for scheduling (Herbaty, 1983).

The second week schedule is more of an announcement used to point out subsequent jobs and tasks that is coming up. Weekly schedule meetings should be held to assist the planners and the related departments on the types of works that have been scheduled and also to confirm that all the required craft, materials and tools are available (Niebel, 1994). It must be understood that the weekly schedule should be realistic and should provide for an allowance for absenteeism.

This will prevent the occurrence of lack of manpower required to perform the weekly scheduled tasks. “Approval” of the recommended weekly schedule in advance by operation is a good way of ensuring that successful execution of a well-planned schedule.

D, Daily Schedule

The daily work schedule is compiled from the weekly schedule by the maintenance supervisor and is to be distributed the day before the schedule task. The need for such a schedule is due to unforeseen changes in the planned weekly schedule. The reasons may be due to some planned work taking more time than anticipated, shortages in materials or parts, high rate of absenteeism or unexpected high rate of emergency work (Niebel, 1994).From this daily schedule, the jobs are assigned to craftsmen through work orders. The work orders will provide all relevant details such as materials, special tools, a checklist of items requiring performing of maintenance work, and also a feedback column. The daily schedule allows for better control of the maintenance workforce and also caters to any emergency repairs to be performed so as to keep the downtime or severity of the equipment to a minimum.

2.10. Organizing the Maintenance Department

There has always been a requirement that a maintenance department hires and keeps qualified mechanics, trainees and supervisors. Increasing labour costs necessitate a constant emphasis on recruiting, selection and hiring. Staffing, however, does not stop with the completion of the hiring process. Training for maintenance personnel is required to improve the skills of the existing labor force (Keith, 2008). If equipment complexity increases faster than the technical capability of mechanics, the gap will cause a decline in productivity. This gap can be kept closed by additional training of the work force to meet the maintenance requirements of the newer equipment. The management function of organizing is the development of the organization structure and authority-relationship required to achieve selected objectives.

Therefore, organizing the maintenance department means the grouping of activities necessary to achieve the mission of the department and the assignment of each group to a supervisor. Proper performance of organizing can lead to substantial cost savings. These savings can be achieved in labor, material, and capital investment of the maintenance shop. The Organizational Structure of Field Equipment Service Department is shown in the figure 2.5 below.

Company Name: Wonji-Shoa Sugar Estate (WSSF, 2017).

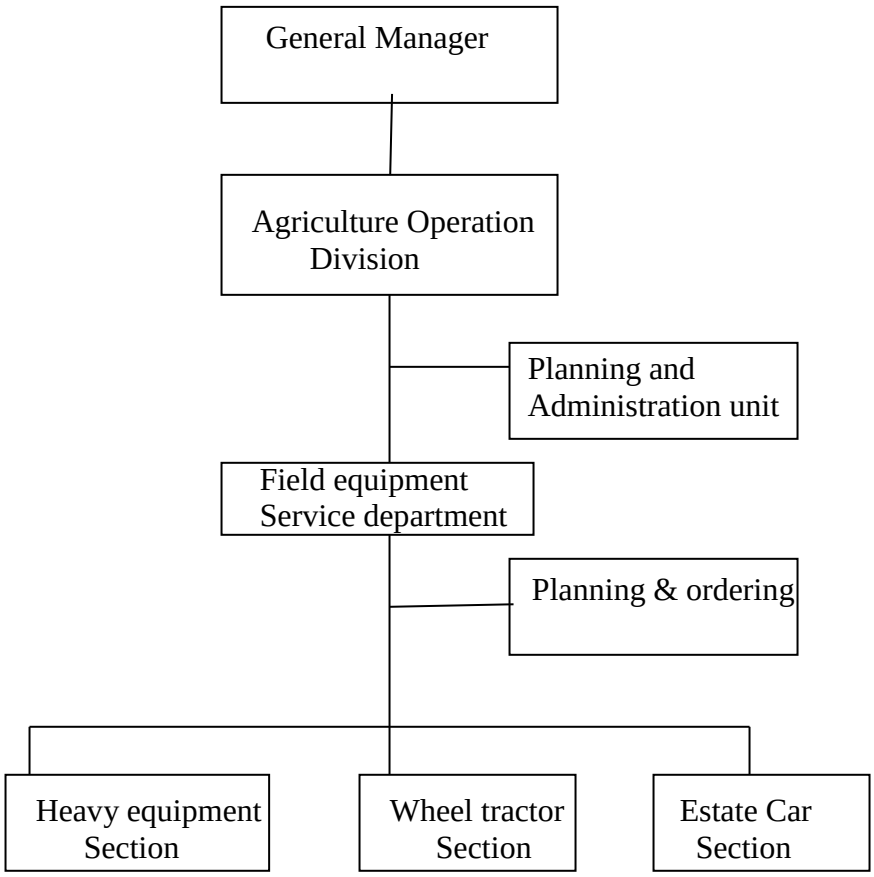


Figure 2. 5.Organizational Structure of Maintenance Department

2.11. Training Maintenance Personnel

Training should be mandatory for maintenance personnel as it is one of the ways to increase productivity. Training, that the mechanics require, is interpersonal skills, the ability to function within teams, problem solving, decision-making, job management performance analysis and improvement, and technical skills.

The organization may have today's levels of technology, but maintenance people have yesterday's set of skill. Thus, they must be trained to bridge the gap. Special effort should be given to the people on the staff who deliver the on-job-training. These informal trainers need instruction and back-up materials on how to teach adults. Technologies are changing, skills must change too (Higgins et al., 2002).

2.12. Estimating the Farm Machinery Costs

Machinery and equipment are major cost items in farm businesses. Larger machines, new technology, higher prices for parts and higher energy prices have all caused machinery and power costs to rise in recent years. Maintenance budget of FESD was very high and it increases at the rate of 18.25% production cost per annual (Amana. 2010), this resulted in reduction of profitability of sugar cane production and increased additional cost.

A machine operating costs analysis take place at any specific point of time However, it regularly involves capital investment.(Edwards et al., 2001) Farm machinery costs can be divided into two categories: fixed cost (ownership costs), which occur regardless of machine use, and variable cost (operating costs), which vary directly with the amount of machine use. The true value of these costs is not known until the machine is sold or worn out. But the costs can be estimated by making a few assumptions about machine life, annual use, and fuel and labor prices. Ownership costs (fixed costs) include depreciation, interest (opportunity cost), taxes, insurance, housing and maintenance facilities.

2.12.1. Farm Machinery Fixed Cost.

Langemeier and Taylor, 1998, stated that the fixed costs are independent of machine use. The annual fixed costs can be calculated based on the relationship between fixed costs items and the new value of a machine. He mentioned the costs items as: Depreciation, Interest, Insurance, Taxes, and Housing.

A. Machinery Depreciation

Begg et al., 1987, stated that, depreciation or capital consumption measures the rate at which the value of the existing capital stock declines with time as a result of wear and tear or obsolescence. The degree of mechanical wear may cause the value of a particular machine to be somewhat above or below the average value for similar machines when it is traded or sold.

The economic life of a machine is the number of years for which costs are to be estimated. It is often less than the machine's service life because most farmers trade a machine for a different one before it is completely worn out. A good rule of thumb is to use an economic life of 10 to 12 years for most farm machines and a 15-year life for tractors (William, 2008).

Salvage value is an estimate of the sale value of the machine at the end of its economic life. It was the amount you can expect to receive as a trade-in allowance, an estimate of the used market value if you expect to sell the machine outright, or zero if you plan to keep the machine until it is worn out (Kastens, 1997).

B. Machinery Interest

If you borrow money to buy a machine, the lender determine the interest rate to charge. But if you use your own capital, the rate to charge depend on the opportunity cost for that capital elsewhere in farm business. The interest rate should be adjusted by subtracting the expected rate of inflation. If capital was borrowed to finance the machinery investment, that cost should be at least large enough to cover the interest paid on the loan. According to Siemens and Bower (1999), interest is a large expense item for agricultural machinery. It is a direct expense item on borrowed capital. Even if cash is paid for purchased machinery, money is tied up that might be available for use elsewhere in the business. Interest rate varies but usually will be in the range of 8 to 10.

C. Machinery Insurance

Insurance should be carried on farm machinery to allow for replacement in case of a disaster such as a fire or tornado. If insurance was not carried, the risk was assumed by the rest of the farm business. According to Goense (1995), insurance is required for tractors and self-propelled machines to cover third part liability when driving on public roads. This in most cases 1% of purchased price.

D. Machinery Housing

There was a tremendous variation in housing provided for farm machinery. Providing shelter, tools, and maintenance equipment for machinery will result in fewer repairs in the field and less deterioration of mechanical parts and appearance from weathering. That should produce greater reliability in the field and a higher trade-in value. In the Netherlands, it is common that, machinery is stored under cover.

According to Goense, (1995) an estimated charge of 0.5 percent of the purchase price was suggested for housing costs. However, to simplify calculating TIH costs, they can be lumped together as 1 percent of the purchase price where property taxes are not significant.

TIH = 0.01 x purchase price……2.5

Where. TIH is

T=Tax of the machinery

I=Interest rate of the machinery

H=Housing of machinery

2.12.2. Machinery Operating Cost

Operating costs (also called variable costs) include repairs and maintenance, fuel, lubrication and operator labor.

A.Machinery Repair and Maintenance Cost

Annual repair costs for a given machine normally increase as use increases. However, accurate predictions of machinery repair costs are difficult to obtain. (Johnson, 1979) mentioned that, spare parts required by the machinery are influenced by the type and size of the operation and the service facilities available. Even the repair costs required for identical machines used the same number of hours vary with different types of work or working conditions. For example, a tractor used for heavy work on rough terrain likely will require more repair than one used for light work on smooth terrain. In addition, the amount and effectiveness of preventive maintenance also can influence repair costs. Despite the sizeable problems encountered in specifying repair costs, researchers have estimated accumulated repair and maintenance costs at various stages in the life of most farm machinery. The direct cost of repair and maintenance are presented on two different ways:

- The total life of repair and maintenance costs as a percentage of the machines list price
- Accumulated repairs and maintenance costs as a power function of accumulated machine use.

When only total life of repair and maintenance costs are used it is assumed that they accumulate linear with accumulated life. The variable repair and maintenance costs per hour are following this approach dependent of intensity of machines use (Goense, 1995).

$$RCH = Pp \times \left(\frac{1}{100}\right) \times \left(\frac{TR}{TH}\right) \quad \text{……2.6}$$

Where:

RCH- repair and maintenance cost per hour

Pp - purchase price

TR- total life repair cost as percentage of PP (total accumulated repair cost)

TH- total technical life (total accumulated hours).

$$ARM_{n} = RF_1 \times CLP_n \times [\frac{AHn}{1000}]^{RF2} \quad \text{.....2.7}$$

Where:

ARM- accumulated repair and maintenance cost for n year

CLP (PP) - current list price

AH- accumulated hours

RF- repair factor

n- Number of years (age of the machine) in which RM cost is determined.

Repair and maintenance factors used to calculate repair costs also are reported in the (appendix-I) at the bottom of the cost table presented for each machinery item. It should be emphasized that these repair costs be viewed only as estimates of average repair and maintenance expenditures, even though they are widely used. If available, good machinery repair records will provide a superior basis for predicting repair costs (William, 2009)

B. Fuel and Lubrication Cost

Fuel and lubrication costs for farm machinery vary, based on the number of hours the engine was operated (Siemens and Bower, 1999). Fuel expenditures also depend on the fuel consumption rate per hour and the fuel price.

In turn, the rate of fuel consumption varies according to size of engine, kind of work performed (i.e., the engine load factor), and type of fuel, among other things. Annual average fuel requirements for tractors may be used to calculate overall machinery costs. However, you should base the cost of each particular operation, such as disking or plowing, on actual fuel costs for the power required. According to Siemens and Bower, (1999) the fuel price varies from time to time in order to deviation the Coefficient of Fuel Requirements required as in the table 2.1.

Table 2. 1.Multipliers or Coefficient of Fuel Requirements

Engine fuel type	Average fuel consumption (gallons per hour per rated PTO hp)	Typical Lb/gal
Gasoline	0.068	6.1
Diesel	0.043	6-9
L. P. Gas	0.080	4.25-4.5

Source: Siemens and Bower, (1999).

Langemeier and Taylor (1998), calculated fuel and lubricants cost in the following steps:

a) Fuel cost,

Average fuel consumption in gallon per hour ($Q_{av)}$).

Q_{avg} = 0.060 × maximum PTO hp (For gasoline engine)…….. ……....2.8

Q_{avd} = 0.044 × maximum PTO hp. (For diesel engine)…….....2.9

Annual fuel cost = F Q_{av} (gal /hr) × Fuel price x Hours used annually……...2.10

Where;-

F= fuel multiplier and

Q_{av} = Average fuel consumption in gallon per hour.

b) Lubricants cost,

Lubrication costs for all machinery are estimated to be 15 percent of the fuel expenditures, so annual fuel costs are multiplied by 1.15 to determine lubrication and fuel costs (Norm, 2008).

C. Labor cost;

According to Edwards, et al., (2001), stated that actual hours of labor usually exceed field machine time by 10% to 20% because of travel time and time required to lubricate and service the machine, and consequently labor cost can be calculated by the following formula:

Average labor cost = Labor wage × 1.2…… …..2.11

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Materials

The Primary and secondary data concerning the machinery/equipment maintenance management system at Wonji-Shoa sugar estate farm were collected through: structured questionnaires, structured and unstructured interview, observation and documents from field equipment and service department (FESD), land preparation and cultivation team (LPCT) and finance department of the estate farm to analyze the status of maintenance management system of farm machinery.

3.2. Description of Study Area

The Wonji- Shoa Sugarcane Factory lies downstream of the Koka Dam in the Central Rift Valley of Ethiopia in the upper Awash River basin around 10 km from Adama within the geographical boundaries of 80^0 21' to 80^0 29' N latitudes and $390^0$12' to 390^0 18' E longitudes at an altitude of about 1,540 m above sea level. Currently the sugar estate farm is cultivating more than 9352 hectare of irrigated land using overhead irrigation system.

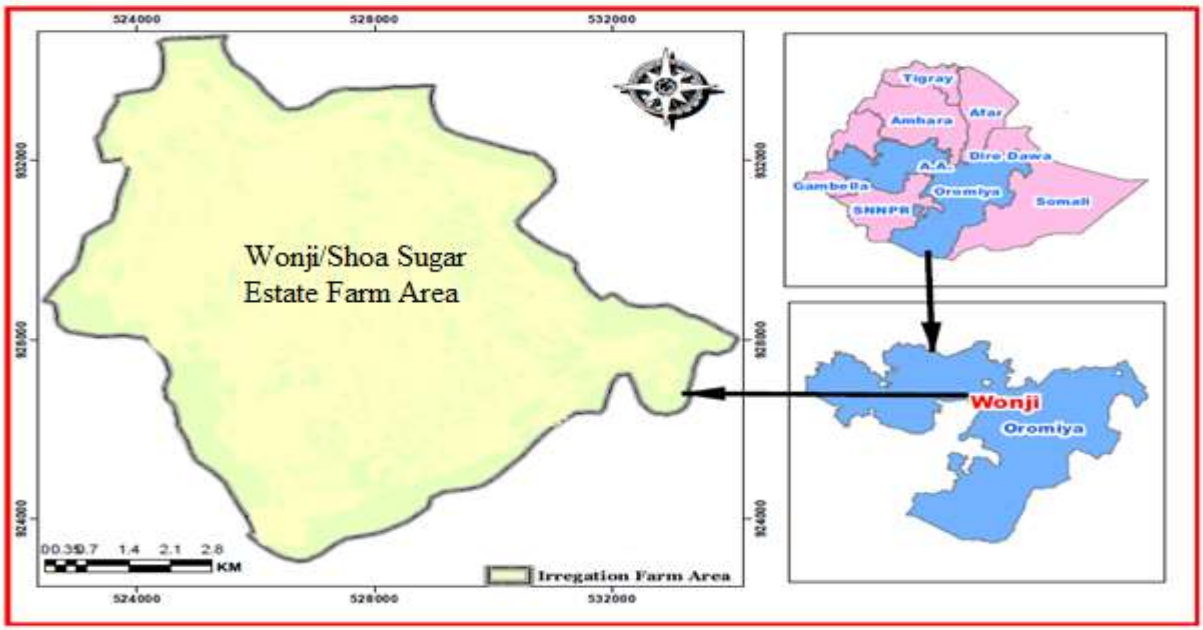


Figure 3. 1.Location and Topographic Map of Study Area

3.3. Research Methods

The study used primary and secondary sources of data. The relevant primary sources contain original, row and unprocessed data. The relevant secondary data were collected from documents, maintenance technical manual, monthly and annual reports of field equipment and service department(FESD), land preparation and cultivation team (LPCT) of the of sugar estate. Data collection was quantitative and qualitative in nature. Quantitative data was a data which express anything in quantity, in number, in percentage and can be measured. Qualitative data which express anything in quality like good, fair, poor, sufficient, insufficient etc. the methodology has more qualitative nature because of the fact that express anything in quality.

3.3.1. Survey Methods and Approaches

A survey on the overall machinery maintenance management situations was conducted in Wonji-Shoa sugar estate from February, 2018 to September, 2018. Primary data were collected through structured questionnaire on maintenance personnel. The study was targeted on machinery maintenance practices and associated factors. The questioner which was distributed to farm machinery maintenance department was attached in Appendix-A.

Close-ended structured questionnaire was developed for this study because of it provides a greater uniformity of responses and to make it easier for analysis. The major contents of the questionnaire were related to the skill of maintenance personnel, training program, maintenance planning and scheduling, maintenance work order, maintenance inventory and purchasing, availability of spare parts and maintenance implementation. In order to have clear interpretation in some sort of quantitative sense, most of the close-ended items of the questionnaire were designed on a four point rating scale ranging from “very good” to “poor”. All of the items were also designed on multiple choice forms.

Another instrument used in this study was structured and unstructured interview. It was employed as instrument of data collection in order to get additional information and to fill the gap during structured questioners from the concerned maintenance personnel of the FESD that was skilled and semi-skilled mechanics. It was administered on one–to-one basis with investigator asking questions and listened to the responses of the mechanics. The questions of the interview were attached at (appendix B).

Physical observation was also made on the current existing maintenance activities and records of the maintenance department of the company. The researcher observed the maintenance activities from February, 2018 to September, 2018 in different sections of the maintenance department in WSSF.

3.3.2. Sampling Method

A total of 114 respondents who were randomly selected from the maintenance department of WSSF to fill the questionnaire on the statues maintenance management system of the sugar estate using structured questionnaire sheets. There are three sections in the maintenance department namely: (i) heavy equipment (ii) wheel tractor (iii) estate car. From each section the respondents were randomly selected using stratified sampling techniques.

Moreover, interview was conducted for skilled mechanics and semi-skilled mechanics, totally 12 mechanics were randomly selected from all sections. The interview was administered on a one–to-one basis with the researcher asking questions and listening to the responses of each maintenance technician. Recorded data and periodic reports on equipment availability, operating costs like fuel, lubricant, oil and maintenance costs collected for analysis of maintenance activities in the WSSF.

3.4. Method of Data Collected

The empirical data in the case study has been collected through Primary and secondary data sources. The Primary data collected through questionnaire, Interview, and physical observation in the maintenance department of the sugar estates in order to get direct information about maintenance practices. While, the secondary data collected from existed maintenance recorded documents. The figure in 3.2 show the methods of data collection during the study.

A, Documents

Researchers are expected to read, understand and critically analyze the writings of others, whether fellow researchers, practitioners. In the research performed, different documents such as maintenance strategies, maintenance audits, maintenance organization charts, maintenance activities and others have been studied. Relevant documents provide reliable data in order to reach the real outcome.

B, Interviews and Quaternary

The interview method of collecting data involves presentation of oral-verbal stimuli reply in terms of oral-verbal responses. This method can be used through personal interviews.The performed interviews have mainly been through personal interviews and the respondents have been maintenance managers.

C, Observations

The observation method involves the researcher in watching, recording and analyzing events of interest. The observations have mainly been performed by observing the status of the company's workshop. When possible, direct observation of maintenance-related meetings as well as participating in internal and external audits at the company.

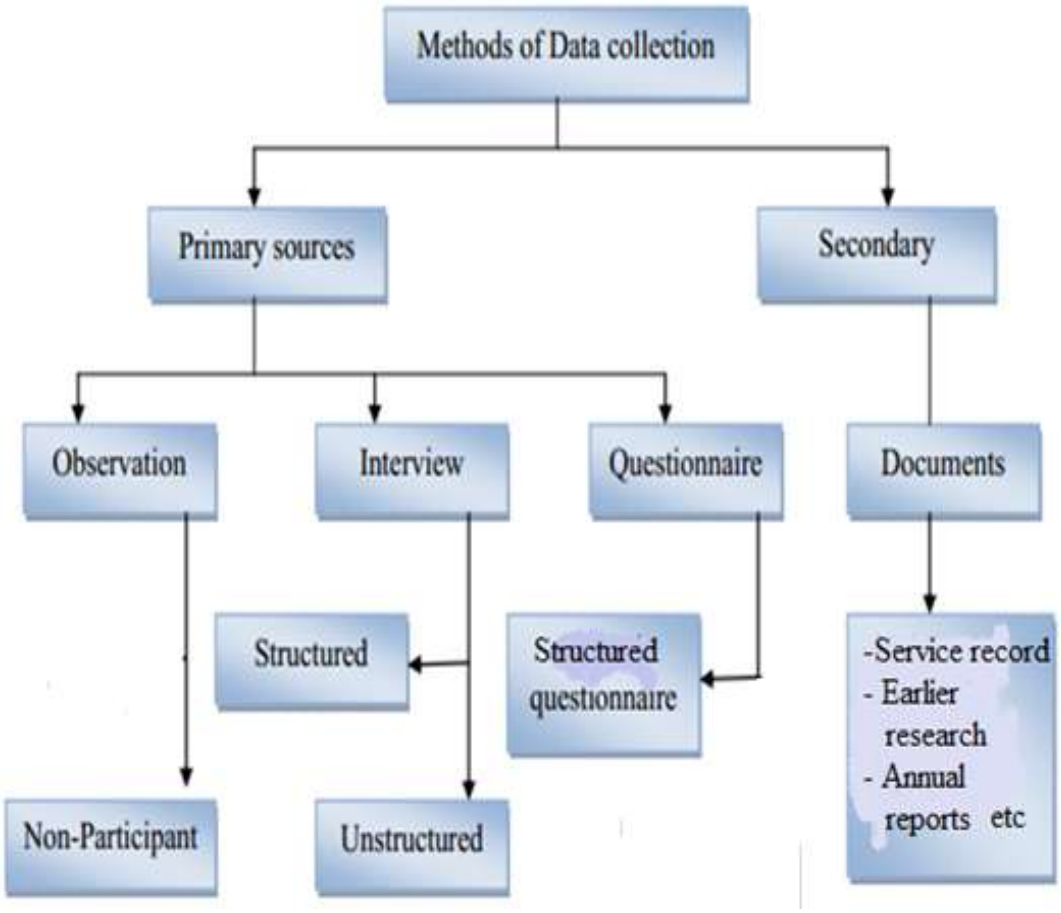


Figure 3. 2.Method of Data Collection

3.5. Data Collected

The types of data collected for the case study through questionnaire, observation and recorded documents on manpower and employ characteristic, training program ,maintenance planning and scheduling, maintenance information & work order, maintenance organization of the dep't, maintenance program implementation, maintenance inventory and purchasing from field equipment and service department (FESD), land preparation and cultivation team (LPCT) and Finance department of the sugar state farm included the following:

1. Types of machineries use in the sugar estate farm for different operations
2. Machinery specification data, which include: make, model, power and machinery age.
3. Machinery maintenance policy and strategic planning in the maintenance department.
4. Maintenance information, Organization and implementation in the maintenance department
5. Machinery costs (theoretical/projected data and actual data), type of work, annual hours of use, annual repair and maintenance expenses, fuel and lubricants consumption and Machinery expected life.

3.6. Machinery cost determination

A. Machinery Insurance

According to Goense (1995), insurance is required for tractors and self-propelled machines to cover third part liability when driving on public roads. This in most cases 1% of purchased price.

B. Machinery Housing

According to Goense, (1995) calculating TIH costs, they can be lumped together as 1 percent of the purchase price where property taxes are not significant.

TIH = 0.01 x purchase price……3.1

Where. TIH is

T=Tax of the machinery

I=Interest rate of the machinery

H=Housing of machinery

C. Maintenance and repair cost

The accumulated repair cost can be calculated through the following equation (ASABE, 2015).

$$ARC = NEP \times RF1 \times \frac{(\text{Accumulated Hours})^{RF2}}{1000} \quad \text{.....3.2}$$

Where

NEP = new equivalent price of a machine,

RF1 and RF2 are repair factors.

According to ASABE (2015), the RF1 factors hold be 0.007 for two wheel drives and 0.003 for four wheel drives and crawler tractors.RF2 is 2.0 for all three tractor classes. The recorded repair and maintenance was used in this study.

D. Fuel consumption

Fuel consumption vary with the use of machine. Average fuel consumption, in gallons per hour, for farm tractors on a year-round basis without reference to any specific implement can also be estimated with the equation as follows (ASABE, 2015).

Average fuel consumption = 0.044 x max PTO hp for diesel engines.....3.3

$$\text{Average fuel cost} = \left(\frac{\text{Average fuel consumption}}{\text{hour}}\right) \times \frac{\text{Birr}}{\text{gallon}} \quad \text{.....3.4}$$

E. Lubrication

Surveys indicate that total lubrication costs on most farms average about 15 percent of fuel costs. Therefore, once the fuel cost per hour has been estimated, it is just needed to multiply it by 0.15 to estimate total lubrication costs (Norm, 2008). The current oil and lubricant cost determined at rate equivalent to birr/hour. Then the oil cost per hour calculated by the following sequences:

• Oil cost per hour = 0.15 × fuel cost per hour.....3.5

3.7. Data Organization and Methods of Analysis

The procedure that was followed to analyze the data was different depending on the nature of the instruments employed. Hence, the researcher used the following techniques of data analysis: first the data collected using the questionnaires, interview and observation were organized,

entered and analyzed using Microsoft Excel 2013 .Because of the descriptive nature of the study mainly percentages in confidence of interval and mean score values were used as appropriate means to analyze the collected data using close-ended items.

The data of open-ended items of the questionnaire collected by interviews were analyzed qualitatively and quantitatively. The collected data were identified and categorized in line with their similarities. Moreover, findings were established using tables and graphs, in order to create convenience for understanding summary of the data.

Data obtained from the observation were arranged in such a way that variables were created based on questionnaire order and along the respondent's categories and tabulated using Microsoft Excel 2013 .Finally evaluate the current status of maintenance practices in WSSF with maintenance bench mark implementation at world classes.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Questionnaire Assessment

One of the main components of the properly organized process of the machineries and equipment supervision in any enterprise is the choice and the use of proper management strategy. In order to investigate the current status of the maintenance management system at WSSF the research analyzed based on the summarized questionnaires in the (appendix A) and compare with maintenance bench mark (appendix A3). The major contents of the questionnaire which was randomly distributed to maintenance and service department were related to the skill of maintenance personnel, training program, maintenance planning and scheduling, maintenance work order, maintenance implementation, maintenance inventory and purchasing.

a) FESD Mechanics b) FESD Supervisors and foreman

Figure 4. 1.Questionnaire Assessment of Maintenance Personals

4.1.1. Manpower and Employee Characteristic.

The determination of requirements for manpower involves identifying how many people were

required and what skills they should possess. The educational background of the staff at maintenance and service department were 31.46% whose their profession were not related to the maintenance work as seen from the table 4.1 and figures 4.2, these affected the maintenance quality. The other important in manpower characteristics as seen in the figure 4.3, was 39.82% experience was between 1-5 years. Therefore, in order to have cost effective maintenance the manpower who was qualified on agricultural machinery maintenance and developed the skilled by training. In addition the maintenance management should considered the number of females that should participate in maintenance work was less.

Table 4. 1.Current Educational Background of Maintenance Staff

Educational Profile	Masters Degree	Bachelor Degree	College diploma	Level v	Level iV	Level iii	Level iI	Level I	12th &10th complete	Grade 5-9	Total	%
A.T	-	5	15	59	29	28	13	6	-	-	155	51.32
A. Mech	1	-	1	-	-	-	-	-	-	-	2	0.66
A.Ele	-	-	1	-	1	-	2	7	-	-	11	3.42
GM	-	-	6	-	4	3	2	1	-	-	16	5.29
M .Eng.	-	-	2	13	6	2	-	-	-	-	23	7.62
Other Science	-	10	8	2	11	9	5	3	27	20	95	31.46
Total	1	15	33	74	51	42	22	17	27	20	**302**	
%	0.45	4.97	10.9	24.5	16.88	13.90	7.28	5.63	8.94	6.62	100	

A.T- Automotive Technology, Ag .Mech- Agricultural Mechanization, A.Ele -Auto, Electricity, GM- General mechanic, Material Eng.-Material Engineering, Other Science (Business, Economics, Accounting and Civil)

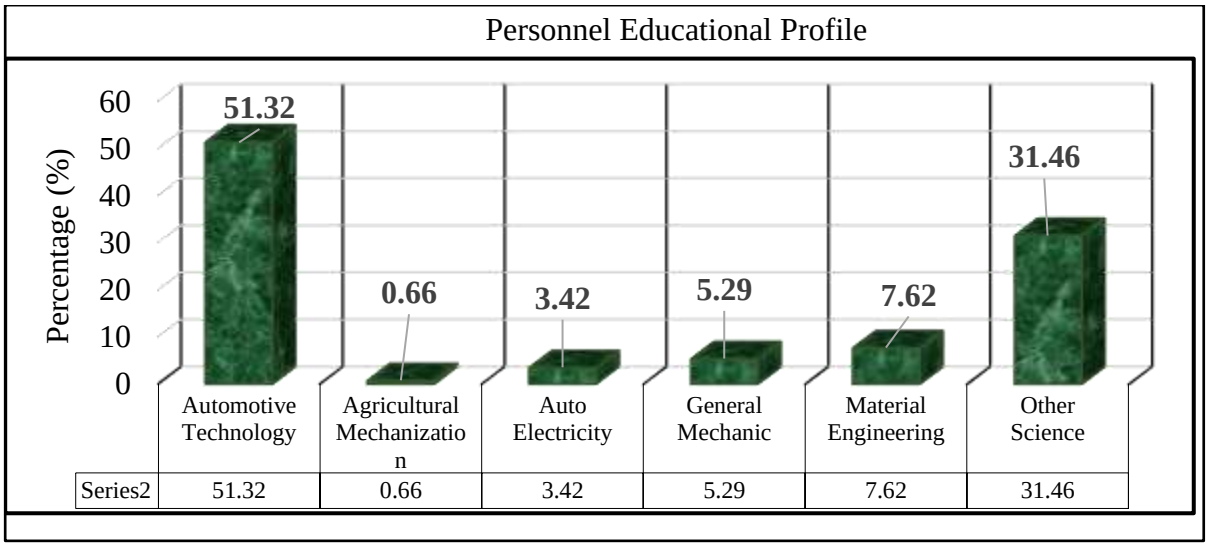


Figure 4. 2.Current Educational Profile of Maintenance Staff

Table 4. 2.Questionnaire Assessment on Experience of Maintenance Staff

Sex	Experience in rage				
	1-5	6-10	11-15	16 & Above	Total
Male	44	14	28	26	111
Female	1	1	-	-	2
Total	45	15	28	25	113
Percentage (%)	39.82%	13.27%	24.78%	22.12%	100

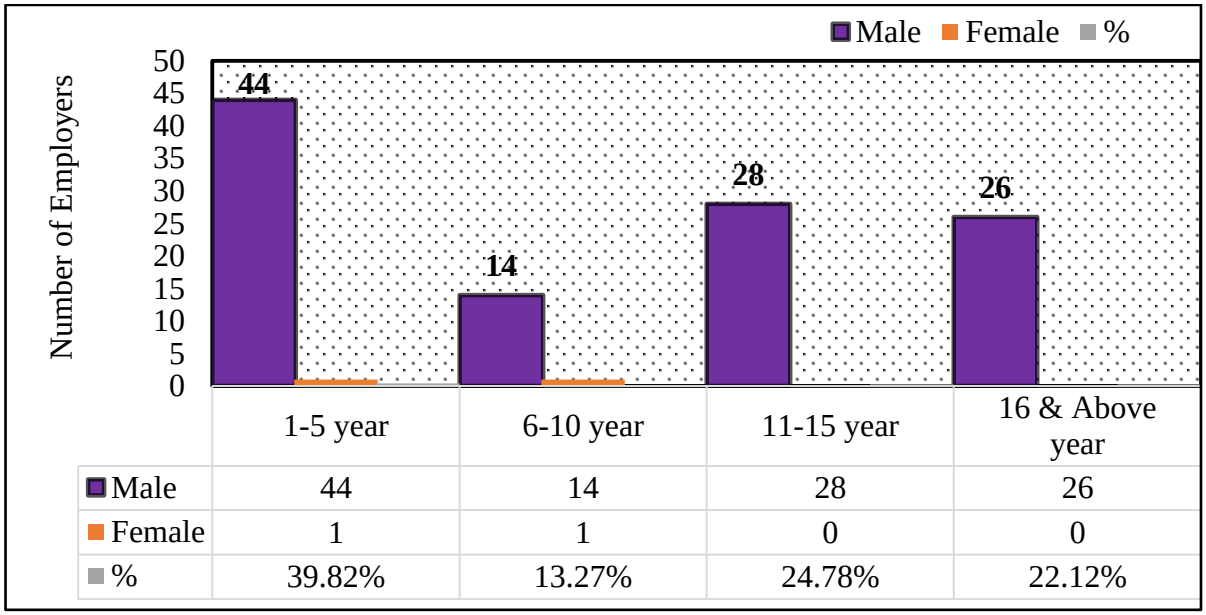
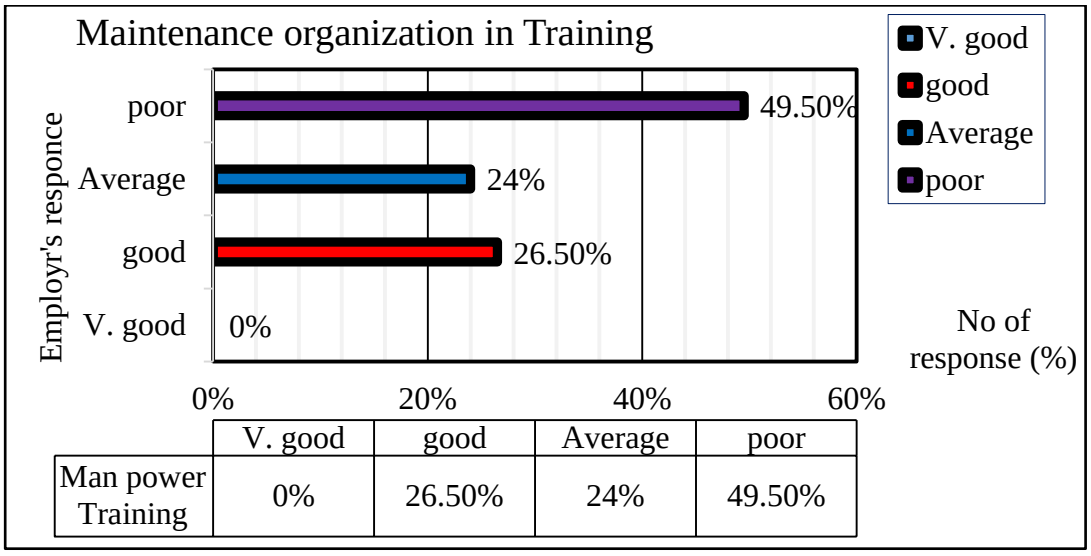


Figure 4. 3.Experience of Maintenance Staff.

4.1.2. Maintenance Organization in Training program.

As seen in the (appendix C), the sugar estate has deferent vehicles or machineries were available to be maintained. In order to have quality maintenance process, the department should be organized with good maintenance tools in quality and quantity, availability of maintenance planner and continuous training was essential to cope up with the dynamic advancement of technology and to compete with the market change.

The maintenance and service department did not had policy on training. However, the importance of training becomes mandatory if new vehicles or equipment imported whereas the machinery becoming advanced. Unskilled maintenance workers were one of the problems of the maintenance department. Therefore, providing of training to maintenance workers should be the basic and the primary aim for the estate farm in order to achieving quality and quantity of agricultural operations. Figure 4 1.show the questionnaire assessment on manpower training



	V. good	good	Average	poor
Man power Training	0%	26.50%	24%	49.50%

Figure 4. 4.Questionnaire Assessment on Manpower Training

From the assessment the frequency of maintenance training, the quality and skill level of maintenance personnel have higher negative impact on maintenance work quality. Training develops confidence of maintenance personnel and fill the skill gap. Therefore, training for maintenance personnel was very essential to improve the skills of the labour force.

However, 49.50% of manpower training on general quality in maintenance, average skill level of the employees, the type of training given in the classroom, supported with laboratory exercises and the frequency of maintenance training were 49.50% poor. Therefore, as the equipment complexity increases faster than the technical capability of the mechanic skill gap had cause a decrease in machinery maintenance quality and sugar productivity.

4.1.3. Maintenance Planning and Scheduling

The planning and scheduling assessment includes, annual work plan implementation rate, preventive maintenance program completed within the planned time, commitment of maintenance management on schedule monitoring and planning effectiveness when comparing the actual and estimated time. From the study with selected major variables on maintenance planning and scheduling implementation 40.7 % were accomplished on average in the sugar estates as indicated in the figure 4.5.

The other important to be considered were maintenance checklists which has higher negative impact on maintenance planning and scheduling accomplishment. Especially, it was known that lubrication check lists were major parts of any successful maintenance planning program. It requires application of the right lubricant at the right time, in the right quantity using the right method with in the planned and scheduled time. In which it ensures long life and safe working of the equipment.

A proper lubrication converts solid friction into fluid friction and thus reduces wear and tear of moving parts and cuts down power consumption. It also keep bearings within allowable temperature ranges and protect them from rust, dust and corrosion. Therefore, lubrication were major part of preventive programs guarantees long life of equipment and its components without failures. The maintenance check list recommend in (appendix G) for all maintenance activity done were important to control planning and scheduling effectiveness.

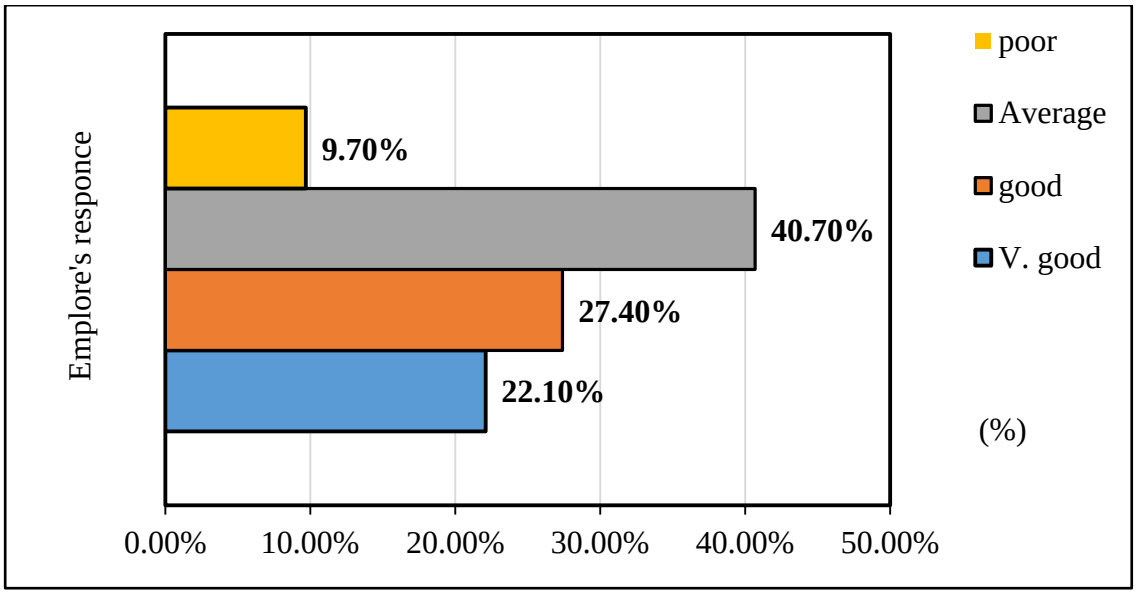


Figure 4. 5.Questionnaire Assessment on Planning and Scheduling Implementation Rate

4.1.4. Maintenance Information and Work Order

The existing maintenance work flow is considering mostly the corrective maintenance and the assigned maintenance personnel perform the job according to the order of work flow, the work order is mostly oral not in written form.

As indicates and seen from the figure 4.6 below all the maintenance activity records and documentation include planning the work orders, Non-emergency work orders completed within the planned time, planned work orders experiencing no delays and Maintenance man-hours reported to a work order were not computer based rather it was traditional which indicated 63.70% was poor.

As a result, the maintenance information and work orders available for historical data analysis has higher negative impact on maintenance records and documentation in field equipment service department.

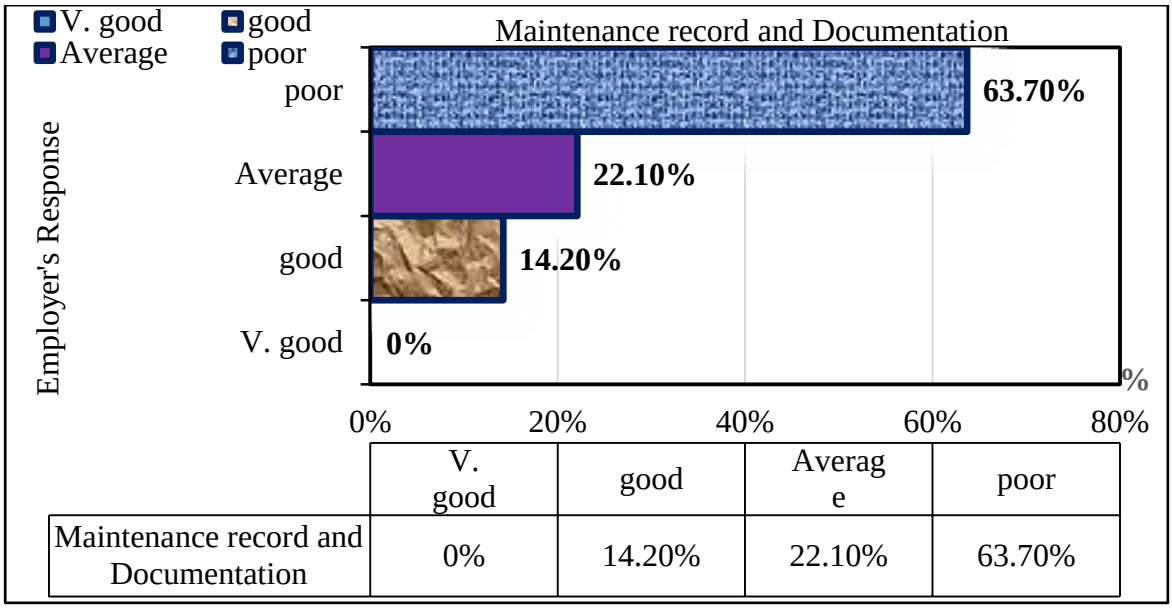


Figure 4. 6.Questionnaire On Maintenance Record and Documentation

In order to have good maintenance record and documentation the assigned maintenance personnel when performing the repair work at the same time writes the checked parts on the check list indicated on the maintenance work order sheet in (appendix H)

4.1.5. Maintenance Organization of the Department

The way the organization was structured i.e., organizing by shop has an advantage in specialization of the work done in the shop and it was easy to assign the right skilled manpower. However, the structure by itself lack of machinery familiarity by the mechanics which highly affect the maintenance accomplishment. To avoid this, the maintenance department separated the mechanics, foreman and supervisors in the three sections; heavy equipment, wheel tractors and estate car sections.

Thus, the structure became good enough regarding this problems to accomplish the maintenance task. However, the variable such as, use of job description, availability of maintenance planners, Maintenance tools/equipment quality and quantity, Condition of maintenance shop work area layouts as show in the Figure 4.7 and Maintenance management effort and attitude have higher impact on maintenance activities.

4.1.6. Maintenance Program Implementation

The main task of the maintenance department was to carry out preventive and corrective maintenance according to maintenance plan and schedules to improve availability of machinery quality, decreased maintenance time and increased agricultural operations. From the assessment, the PM inspection/task checklists which were checked to ensure completeness, the machineries covered by a PM program, the PM program was checked against an equipment item's history annually to ensure good coverage and the frequency of a PM inspection or task/service interval has higher negative impact since the machinery not covered on planned time.

Therefore, maintenance Check lists as in (appendix G) prepared to ensure completeness which used to check recommended in preventive maintenance allows the organization to plan better and reduce maintenance cost. Commonly, the maintenance personnel were usually carrying out breakdown maintenance or corrective maintenance, which caused agricultural operations loss. All machineries should have maintenance check list for the maintenance implementation to be cost effective.

4.1.7. Maintenance Inventory and Purchasing

It is true that most of the managers spend their time on equipment problems and directing people rather than on matters pertaining to spare parts and maintenance consumables. However, the need for spare parts was much more predictable. Since the volume of inventory required is based to a large degree on usage, the fewer parts we use, the fewer we need to keep on hand. The challenge was to determine what a correct inventory should be and how to manage it. From the study as shown in the figure 4.7 below the situation of the spare parts during the study is poor therefore, most the machinery maintain through cannibalization.

In the WSSF Factory, there was no effective and efficient way of spare parts planning and control system. As clearly show in the figure the situation of the spare parts during the study 45.2 % is poor. Neither too little nor too much inventory can be tolerated if a truly effective maintenance operation was desired. Furthermore, spare parts were purchased depending on budget availability without proper forecasts; hence money was wasted on dead stock. The requisition was sometimes prepared for the requirement of spare parts when break down occurs.

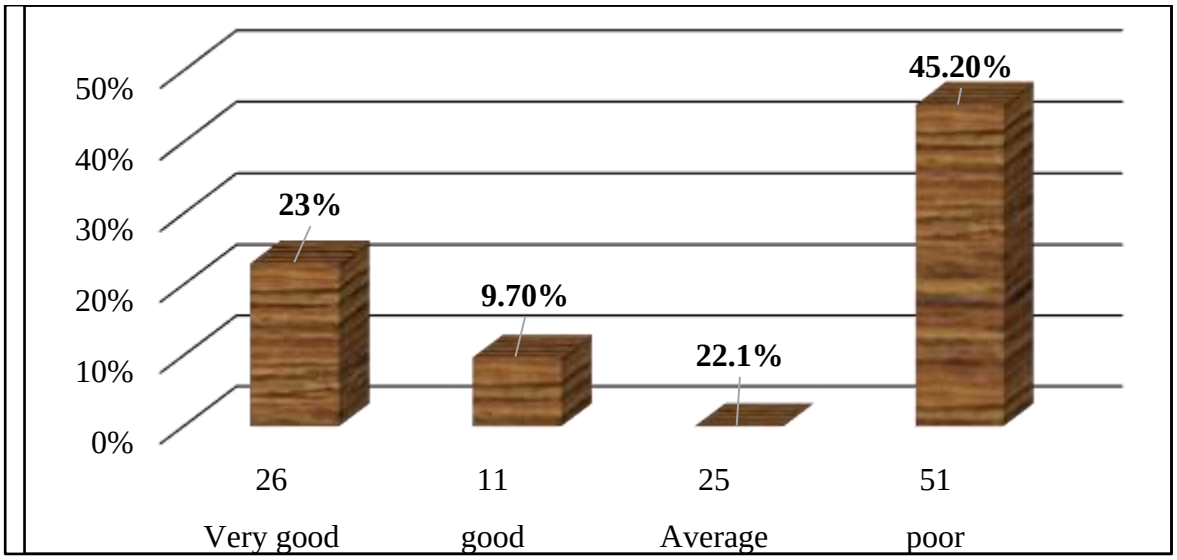


Figure 4. 7.Situation of the spare parts during the study

The other limitation is purchase of non-genuine spare parts, and some non-genuine spare parts with substitute materials were working in the factory which, cause higher frequency of breakdown. This was attributed to absence of reliable and regular suppliers were available. The main cause of this problem was improper materials requirement planning. On the other hand, most of the machines' down time in WSSF was caused by shortage of spare parts. This showed absence of coordination between supply and maintenance departments.

Even though the existence of less management concern was committed, there is a low corrective action. This makes situations even worse. The maintenance organization in each section would function under the direct administrative control of its maintenance chief. In such case, it was advisable to have interchangeable personnel for the maintenance Executives. As can be seen from the Factory organizational chart (Appendix B) the maintenance department of the company is decentralized. Of course, this type of maintenance organization has some advantages like:

- Reduced travel time to and from job
- More intimate equipment knowledge through repeated experience and
- Improved maintenance production relationship.

4.2. Maintenance Assessment through Interview

The interview result indicated that the maintenance work performed in sugar estate farm is more of maintenance after breakdown than preventive Maintenance. The mechanic in department were assigned to maintain machineries in their sections as heavy equipment, tractor and estate cars sections. Planned maintenance activity that was designed to improve machinery and equipment life and avoid any unplanned maintenance activity. It includes the lubrication program plus routine inspection, cleaning and adjustments, 80% of the interviewees said, though there was lubrication program in the company the frequency was in the delayed manner than the scheduled. However, Proper lubrication guarantees long life of equipment and its components without failures.

The main causes to the machinery failures were carelessness of operators during operation, delay in preventive maintenance of machinery and over load of machineries, As 91.7% of the interviewees stated the maintenance department there was no sufficient on job training program and the interval of the training was not regular. Sometimes two years on the other times in three years. The training center was not well equipped with training materials and the trainers. Most of the training was theoretical instead of being practice oriented. On the job training was the most common method for training maintenance personnel. Most of the interviewees added that they maintain machineries without having the manufacturer's service manual for maintenance.

As 85% of the interviewees said it, the farm machineries maintenance workshop in the sugar estate farm was very small. Even if the number of machineries increased by five to six fold from the previous number the workshop remained the same. Therefore, since the workshop was very small in size it was difficult to maintain the machineries. This makes the maintenance works to be delayed. The mechanics were not given adequate attentions or motivations, no incentives and there was scarcity of spare parts, lack of proper tools, which facilitate the work. Furthermore, there was no sufficient on job training program. Hence there was a high skill gap among maintenance personnel.

4.2.1. The Existing Maintenance Management System.

According to this study the existing maintenance system in the sugar estate farm was mostly maintenance after breakdown and work based on emergency and priority though, the practice of preventive maintenance system was minimum. The maintenance department was not following a well-planned and a systematic way of maintaining farm machines. This has come from lack of proper maintenance management because always the management was reported to be subjective to production operations ignoring farm machinery maintenance function.

Even though, the target of the organization was to obtain quality and quantity of sugar product for the achievement of yearly profit that was projected by production planning and control department. These can be achieved by if good maintenance management existed. Therefore, the management should deserve considerable attention to the maintenance department for the achievement of the target profit.

The other main problem faced by the maintenance department was lack of spare parts to maintain the breakdown of machineries. As a result most of the machinery maintenance work done by cannibalization, modification and scarifying one machinery to replace the spare parts used for the other machineries. Therefore, some of the farm machineries were not properly maintained and they stop for a long time. This was due to the management given less attention on the maintenance inventory and purchasing of the spare parts. Unplanned preventive maintenance and shortage of the spare parts that leading to higher machinery downtime of machinery.

4.2.2. Work Shop Facility

From the study maintenance shop work area location and maintenance tools/equipment quality and quantity has higher negative impact on maintenance implementation of the maintenance in the field equipment service department. The maintenance workshop area location should not be comfortable for rebuilding, assembling, disassembling and overhauling of machine components. Preventive or breakdown maintenance works need a well-organized workshop to perform mechanical job. The existing workshop is not organized workshop. Having presented the existing situation of workshops, equipment’s and tools in maintenance and service department is 33.60% is poor.

According to this assessment, there were insufficient workshop, equipment/tools to assist the current maintenance and repair activities. It was observed that the equipment and machineries are frequently failed these affect the performance of machineries therefore, the maintenance management should give attention.

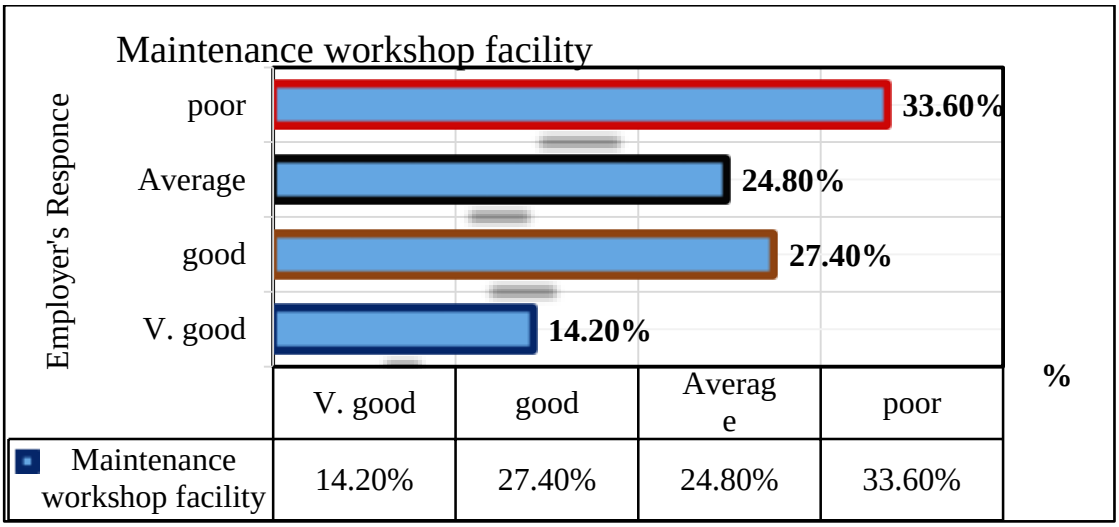


Figure 4. 8. Assessment on Maintenance Workshop Facility

The following comments and recommendations were made, Poor maintenance workshop facility influences the quality of maintenance and efficiency of technical personnel. Therefore, it was recommended that purchasing new and precise equipment's and hand tools within the budget year deserve priority. Due to absence of special tools and testing instruments in the maintenance department, conditions of machines were not properly monitored. As a result higher frequency of breakdown maintenance was occurring.

The maintenance department (FESD) maintains all types of farm machineries in the maintenance and service department. All of the three the maintenance sections have their own shop, equipped with different machineries. The machineries are arranged in their type. However, the location of each machinery in the shops was not suitable for the maintenance workers. The details of the three shops heavy equipment, wheel tractors and estate car sections would be discussed here under.

(A). Heavy equipment shop

It was the biggest shop among the three shops. The shop comprised of maintenance operations, like welding different machinery components, engine rebuilding, disassembling and reassembling. Maintenance of these machineries in the shop was able to consist different parts, which can replace the broken or wear items. Besides this operation, modification work and other simple machineries parts can be built in the shop. The shop was also staffed by qualified senior skilled mechanics, semi-skilled mechanics, and assistant mechanics.

(B). Wheel tractors and Estate cars shop

This shop was also equipped with different types of tool and machineries with different horse powers were found. The main operation performed in the shop was repairing these tractors and make them ready for agricultural operations. There were qualified skilled mechanics and semi-skilled mechanics that perform these activities well. The maintenance of wheel tractor part of the machineries was totally falling on this shop. It was observed that there was some knowledge gap between the mechanics and the new technology. For instance new machineries were controlled by ECM (Electronic Control Module). In this respect, unless training was given in these aspects it was difficult to maintain such machineries properly. Therefore, frequent training was essential to empower the shop mechanics.

4.3. Visual Observation and Further Assessment

Lack of testing instruments, such as injection pump tester, crankshaft grinder, Liners remover and installing machines and engine electrical test benches was a problem observed during the case study. Due to these problems, mostly a lot of machineries are sent to Addis Ababa to get these services and same recently purchased advanced machinery existed that where faced the problems with engine, transmission and clutch problems also maintained by the mechanic came from supplier. That means a loss of huge amount of money for the company. Due to this, there was higher machinery downtime.

The other problems observed in the company there was higher flow of agricultural machinery for maintenance work need from harvesting, land preparation and cultivation, plantation and civil works departments to Field Equipment Service department for maintenance activities. After receiving the request, the maintenance manager passes the work to the concerned division.

Finally, it reaches to the mechanics through supervisor. The accomplished maintenance work was approved by supervisors and then reported to managers. Due to emergency and priority based and waiting of spare parts for maintenance, a lot of machineries were waiting for maintenance. Therefore, the machinery utilization of the agricultural operation was influenced. Mostly machinery utilization depends on maintenance response, worker motivation and operator machinery assignment. The maintenance response of the company was slow due to the absence of required spare parts,

The workers dissatisfied due to low payment, absence of skilled manpower for the latest machineries and small maintenance work area, there was no fast maintenance response for accidental breakage of machineries due to such problem.

- Frequent accident occurrences
- Lack of work motivation and top management focus to maintenance
- Low productivity of the maintenance department
- Improper stock management and spare part planning
- Lack of using proper maintenance planning
- Work done was solely depending on experience

To minimize the effects of the above problems that face the company the establishment and implementation of effective and efficiently training programs will be one of the important solutions. Generally, the mechanics and operators were not motivated to maintain and operating machineries actively. Instead, they complain about payment and managerial problems. Therefore, the company should develop a system like team incentive that will motivate employees for operation rather than neglecting them.

4.3.1. Maintenance Plan for Various Sections

The maintenance plan includes:

- Heavy equipment section
- Wheel tractor section
- Estate Section

Maintenance programs were as an input for preparation of maintenance plan. Maintenance program was the set of maintenance activities that were planned to be accomplished in a definite interval. Each maintenance program was based on the following factors:

- Manufacture's recommendations based on service life of major components
- Operational conditions
- Age of the machine
- Criticality of machine
- Quality of spare parts and lubricants
- Maintenance history of machine or reported data

Although, it was impossible to present exhaustively all activities conducted during each maintenance programs, only the major tasks that should be performed on all machines of the same category were proposed. The information for different maintenance programs were compiled and organized based on the data obtained from various manufacturers' operation manuals and on discussions held with maintenance personnel of the factory and the observations made by the author. The repair cycle of maintenance plan has been done depending up on the company's working manual for the entire machine.

4.3.2. Current Status of the Machineries

In sugar estate, there are different farm machineries which are used for various agricultural operations. However, the estate has no set/stated replacement plan as well as disposal system. Design and implementation of disposal system was also an issue to be addressed by state farm machineries management system. Due to lack of disposal system many types of machineries are stocked out of service for years against sun and rain hence depreciated (appendix c).

In WSSF annual operating hours of machineries are longer than recommended values. This effect puts machineries under accelerated depreciation and reduces their useful life. As indicated in the figure 4.8 the machinery disposed 50.69 % below economic life**.** If a vehicles were not economical to repair for operation, it should be sold or disassemble for spare parts on time. Therefore, it was better to use them for spare parts by cannibalization wherever possible.

From the discussions made with different maintenance personnel and the visual observation, it was noted that mechanics usually fix the broken parts or damaged machineries without considering the root causes of the occurrence of failures. In effect, the machinery fails frequently with the same cause of failure. On the other hand, for some machinery it takes a long time to fix minor problems and often the repair was temporary.

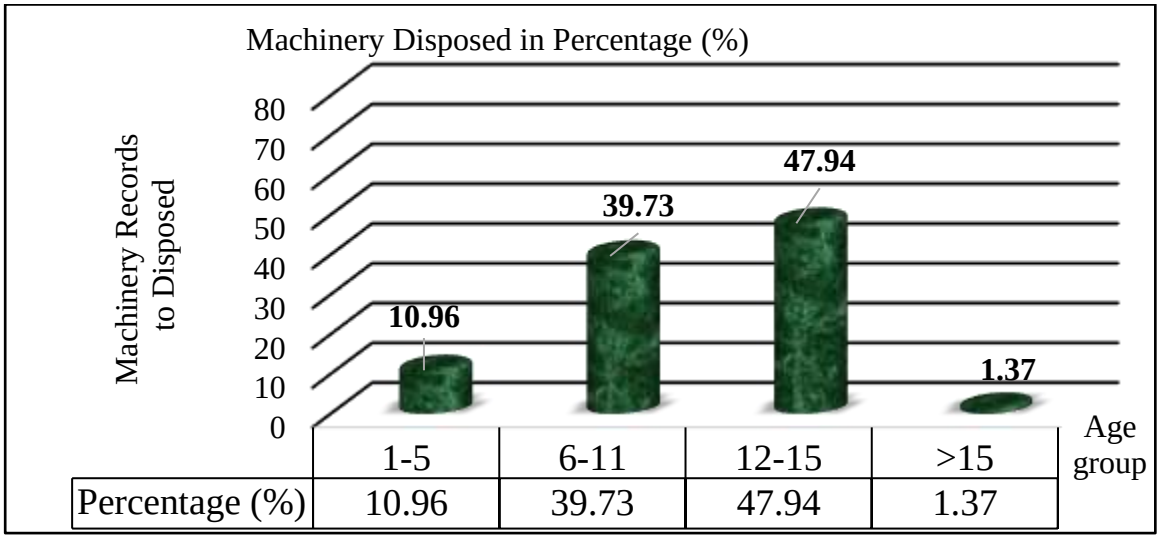


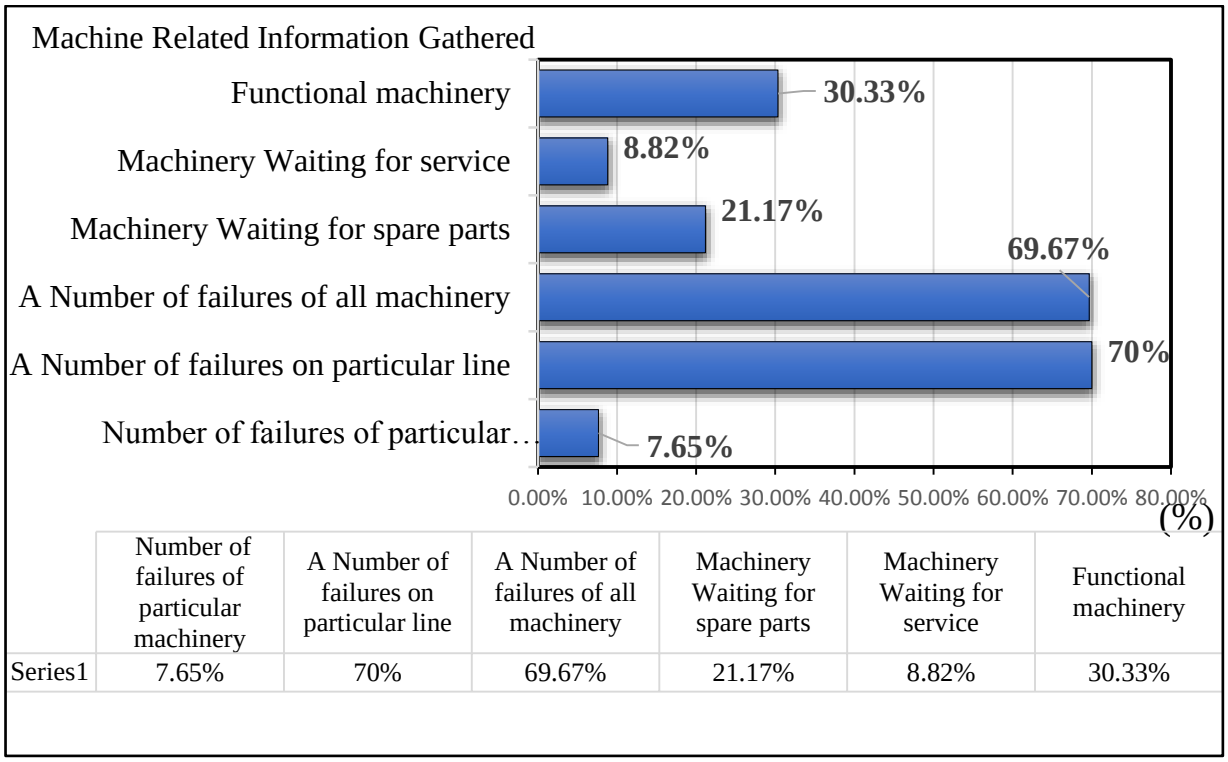
Figure 4. 9. Percentage of Machinery Disposal under Different Age

In addition, Proper categorization of machineries in different status helps to provide cost effective maintenance work. The company should thoroughly identify the machineries status in the regular way. From the machinery status list, observed in greater than 50% of machineries out of work below economic life and bad status which exposes to higher cost due to its maintenance complexity and higher down time as shown in the figure 4.8 above. This was clearly indicated that there was a problem on the maintenance system.

4.3.3. Critical Farm Machineries and their Availability

The performance of farm machineries can be determined by comparing net working hours and down time hours of the machineries within the given period. Net working hours were utilized for effective work whereas down time hours were machineries hours wasted due to the failure of machinery and other reasons. Therefore, the availability of the machineries in the agricultural operations and the critical machineries with their time they spent due to breakdown in the year 2017.

As the in figure 4.8 Most of the main farm machineries in the departments were out of work from their service life below their recommended by manufacturer manuals. Some of them were covered with break down maintenance that increases the down time. From machine related information gathered result indicated in the figure 4.8, Number of failures of all machine was 69.6% therefore, the mechanics were spending more time to repair these machineries which maximize the overtime and reduce the productivity of the company. In order to increase the productivity of the factory, these machineries should cover under preventive maintenance rather than corrective or break down maintenance.



	Number of failures of particular machinery	A Number of failures on particular line	A Number of failures of all machinery	Machinery Waiting for spare parts	Machinery Waiting for service	Functional machinery
Series1	7.65%	70%	69.67%	21.17%	8.82%	30.33%

Figure 4. 10. Types of Machinery-Related Information Gathered in WSSE

4.4. Determination of Preventive Maintenance Repair Cycle

Preventive maintenance calls for taking machinery for repair at planned intervals, so that uncalled for breakdown could be prevented. These intervals are decided mainly keeping in view the complexity of the equipment and its load conditions. The repairs which are carried out at a planned interval under preventive maintenance are:-

- Inspection
- Small repair and Medium repair and Complete overhaul

These repairs are carried out on the machine in a sequence which was well defined for the particular machines. To determine the repair cycle it needs original equipment manufacturer recommendation manual, questionnaire results, interview the maintenance personnel, condition of the machines and author's observations. From the current practice in WSSF, it is very difficult to obtain vehicle history for the purpose of planning preventive maintenance, this is because the history is simply a record of what was repaired, replaced in breakdown maintenance. Most of the records available are kept for the sake of report not for maintenance improvement or for later use

4.5. Farm Machinery Maintenance Orders

As can be seen from the breakdown maintenance activities are fivefold more than the sum of inspection and preventive maintenance. That means the breakdown work highly dominates, which is more than 84%, of the total maintenance activity in the year. This shows that, the existing maintenance planning system of the company cannot reduce the frequent breakdown of the machinery. The current equipment and machinery maintenance activities of the company consist of both preventive and corrective maintenance. But the corrective maintenance activity highly dominates the preventive activity. The annual maintenance report of the company shows the problem was mostly how they plan the maintenance program. It should be the goal of the department to achieve zero breakdowns. But the main duty of the maintenance department in the company was repairing the failed machineries not preventing or inspecting machineries. Thus, this situation urges implementation of a maintenance system, which improves this big number of breakdowns.

4.6. Work Flow of Maintenance

In Field Equipment Service of the Factory, the maintenance activities are performed in two ways; when machinery is broken down that was corrective maintenance and when the work was generated from the maintenance plan. When breakdown occurs, agricultural operation departments inform the maintenance department by requisition paper. After receiving the request, the maintenance manager passes the work to the concerned division regarded to the compliant, if necessary mechanics were assigned to justify the problem. Finally, it reaches to the mechanics through the supervisor. The accomplished work was approved by supervisors and then reported to managers.

On the other hand, preventive maintenance was performed according to the plan. Each section in the maintenance department knows the preventive actions that should be taken within the week. Having the weekly planned sheet, the three maintenance heavy equipment, wheel tractors and estate car, sections assign the supervisory group to accomplish the inspection or other preventive activities. The result is reported in similar ways as in the above. For successful accomplishment of maintenance activities, it was necessary to develop and implement a clearly known workflow system and use different recording documents. This simplifies the task of maintenance and enhances productivity. Due to improper maintenance work flow system, the problems that were observed in the maintenance department as follows:

- Inadequate reporting system to department heads and managers
- Insufficient record system
- Lack of coordination between workers, department and top management
- Inefficient maintenance work done
- Lack of clearly identified maintenance work flow

In addition to the above mentioned problems, the technical personnel and the department as a whole did not try to work based on manuals and procedures. They are rather based on their experience without any analysis of the maintenance efficiency. In general, the existence of the above and other problems cause low productivity of WSSEF technical personnel. Therefore, it was strongly recommended that the company should follow the standard and uniform maintenance workflow system with additional documents.

The existing maintenance work flow was considering mostly the breakdown maintenance and the assigned maintenance personnel perform the job according to the order of work flow, the work order was mostly oral not in written form. The job was checked and submitted to the operation foreman after maintenance job was completed. This will help to compromise conflicting ideas during maintenance work processing. Maintenance activities pass through different steps and require good decision on each step. The maintenance foreman assigns general shift maintenance personnel for preventive maintenance plan work and the breakdown maintenance work order was assigned to shift maintenance personnel.

In the proposed maintenance work flow, the work order was in the written form. Both the breakdown maintenance and the planned maintenance work will be checked by the maintenance foreman. After accomplishing the maintenance work, the machines were submitted to the respective agricultural-operation departments. The proposed maintenance work flow has some benefits. These were:

- The spare part consumption decreases.
- The production quantity and quality increases in the long run.
- The stoppage of machine minimizes. Responsibility of the individual maintenance craftsmen increases.

To conduct maintenance, the maintenance planner from the annual maintenance plans (see Appendix F) writes the work order sheet (See appendix G) and also writes the checked parts from the check list. After filling the work order sheet, the maintenance planner dispatches documents to the maintenance foreman. From the annual maintenance plan, the assigned maintenance personnel when performing the inspection job at the same time works predictive maintenance and writes the prediction on the remark column. The maintenance foremen takes the remark of the prediction maintenance and analyze the condition and assign maintenance personnel for the next work to perform the prediction parts.

4.7. Design Methods of Maintenance Management System

Preparation of preventive and predictive maintenance work order sheet is vital for good maintenance program. In contrast lack of sufficient and clear maintenance formats would lead to poor maintenance failure analysis as in the case of WSSF. In order to avoid these problems the recommended planned maintenance sheets/formats were shown in (Appendix G). The format/sheet was prepared considering the condition of the machines and the weekly maintenance activity.

Even if there was a planned maintenance, machines need maintenance due to accidents happening. For this purpose breakdown maintenance order sheet is necessary. When preventive or breakdown maintenance work was performed, sometimes the works were not finished at the given time or in progress due to spare part problem and maintenance complexity.

In the maintenance department, there were different maintenance works. The work accomplishment in the week will be filled in the weekly report sheet (See appendix-G) by maintenance foreman and reported to the maintenance manager. The maintenance manager evaluates and gives valuable suggestion to the maintenance department. The maintenance foreman will fill the weekly performance activity in the weekly maintenance performance sheet (appendix-G) and the supervisors check and evaluate the performance level and give valuable suggestion to the maintenance worker.

4.8. Estimating Farm Machinery Costs

4.8.1 Insurance

Insurance should be carried on farm machinery to allow for replacement in case of a disaster such as a fire or tornado. In the case of WSSF insurance was paid for machinery on the basis of on road and off road activities. This indicated that the insurance carried for the machinery varies when the machinery on the field operation or off road and during transportation or on road. But in case of lack of data on the insurance of machinery it was not possible to estimate cost of insurance.

4.8.2 Housing

Providing shelter, tools and maintenance equipment for machinery will result in fewer repairs in the field and less deterioration of mechanical parts and appearance from weathering. Even though, housing very important for machineries to be productive in any farm operations, WSSF, was not given any consideration and it was not possible to estimate machinery housing cost rather most of the machineries exposed to rain and sun, which caused them to be depreciate more.

4.8.3. Repair and Maintenance Cost

Maintenance of agricultural machinery was essential to increase the productivity of the machineries since maintenance updates the performance of the machines standard and reliability of machineries. Repair costs occur because of routine maintenance, wear and tear and accidents. Repair costs for a particular type of machine vary widely because of soil type, rocks, terrain, climate, and other conditions. Within a local area, repair costs even vary from a farm to another farm because of different management policies and operator skill.

For the need of analysis of total accumulated repair and maintenance cost of costs of five wheel as shown in the Table 4.3 and crawler tractors in the Table 4.4 were selected and their theoretical/projected plan and actual costs were determined. In order to evaluate the maintenance management at WSSF. The Table 4.3 and Appendix I2a show the theoretical and actual repair and maintenance costs for the selected wheel tractors existed in sugar estate. These costs are depended on the type of maintenance done on the machinery, the operation time and age of the machine. Higher usage of the machine results higher repair and maintenance costs.

Table 4. 3: Theoretical and Actual Maintenance Cost/Hour in Birr for WT

Current Age	Machinery Type	Theoretical Maintenance &Service cost/hr. in the Year			Plate N0	Machinery Purchase price	Actual Service & Maintenance cost/hr. in the Year		
		2015/16	2016/17	2017/18			2015/16	2016/17	2017/18
		Bir/hr	Bir/hr	Bir/hr		Birr	Bir/hr	Bir/hr	Bir/hr
4	JD-5725	45.43	7.48	10.84	WT-0163	789,051.88	47.32	31.75	7.63
5	Bl-17716	6.27	10.05	9.8	WT-0180	2,068,993.38	15.08	16.59	8.0
6	CL-2254	40.71	14.67	27.6	WT-0089	1,822,922.41	56.77	62.45	102.1
11	S-130DT	18.58	47.32	33.81	WT-0075	449,036.74	39.27	78.10	37.08
15	MF-4260	82.53	60.60	26.45	WT-0032	242,269.94	66.28	72.91	51.62

JD-Johndeer, BL-Bell, CL-Camico loader, S - Sami, MF-Massy Ferguson

The Table 4.3 and Appendix I2a above also show the actual maintenance cost was higher than the theoretical or projected costs for the wheel tractors as the machinery age increases and increase in repair and maintenance costs. Higher costs of maintenance and repair parts caused by when increasing;-

- The age of machinery increasing,
- Low quality of the parts or early replacement of the spare parts,
- Improper usage of machines caused by shortage of well-trained maintenance workers and operators.

Table 4. 4: Theoretical and Actual Maintenance Cost/Hour in Birr for CT

Current Age	Machinery Type	Theoretical Service & Maintenance cost/hr. in the Year			Plate N0	Purchase price	Actual Service & Maintenance cost/hr. in the Year		
		2015/16	2016/17	2017/18			2015/16	2016/17	2017/18
		Bir/hr	Bir/hr.	Bir/hr		Birr	Bir/hr	Bir/hr	Bir/hr
2	PPE.350x	21.25	47.23	13.2	CT-0025	4,364,500	93.8	29.14	31.14
8	NHE265	532.9	36.07	66.1	CT-0017	4,009,472	465.7	512.31	563.5
12	KD-41E	352.9	538.63	544.0	CT-0021	899,007	68.3	75.07	738.0
17	CsE1288	273.5	407.55	117.3	CT-0014	161,4102	370.5	782.86	448.3
19	Ct.D4-sr	125.7	862.08	240.6	CT-05	793,052	128.2	140.97	554.2

PPE.350x-Power plus Excavator, NHE-265-New Holland Excavator, KD-41E- Komatsu Dozer, CsE1288-Cass Excavator, Ct.D4-sr-Caterpillar Dozer

As clearly indicated in the Table 4.4 and Appendix I2b most of the crawler tractors in 2015/16 the theoretical repair and maintenance cost were higher than the actual costs this could be due to ;-

- The lower operating hour,
- Non-operational down times of the machines,
- Use of modification and cannibalization method for replacing the spare parts.

However, as the ages of the machines were higher which the machines got frequent breakdown and more spare parts consumption requires more cost per hour in this period.

4.8.4. Fuel and Oil Cost

Fuel and oil were very significant and life for machineries to operate in the required quantity and quality. Therefore, considering the oil and fuel costs of the machineries was vital for the sugar estate. In WSSF most of the agricultural machineries consumed diesel fuel. The theoretical and actual fuel was considered for the selected machineries and shown in the Table 4.5 with appendix I2c for wheel tractors and Table 4.6 with Appendix I2d for crawler tractors below.

Table 4. 5: Theoretical and Actual Fuel Cot/Hour in Birr for WT

Current Age	Machinery Type	Actual Fuel Consumption Rate /hr. in the service years			Plate N0	Machinery Purchase price	Theoretical Fc Consumption Rate in the service years		
		2015/16	2016/17	2017/18			2015/16	2016/17	2017/18
		Bir/hr	Bir/hr	Bir/hr		Birr	Bir/hr	Bir/hr	Bir/hr
4	JD-5725	198	293	250.8	WT-0163	789,052	182	228	206.91
5	Bl-17716	189	171.0	275.8	WT-0032	242,270	171	188.1	206.91
6	CL-2254	770	836.5	906.5	WT-0089	1,822,922	731.5	731.5	804.65
11	S-130DT	330	358.5	389.8	WT-0075	449,037	358	313.5	344.85
15	MF-4260	965	665.0	813.0	WT-0180	2,068,993	910.1	665	804.0

JD-Johndeer, BL-Bell, CL-Camico loader, S - Sami, MF-Massy Ferguson

Table 4. 6: Theoretical and Actual Fuel Cost/Hour in Birr for CT

Current Age	Machinery Type	Theoretical Fuel Consumption Rate /hr. in the service years			Plate N0	Machinery Purchase price	Actual Fc Consumption Rate in the service years		
		2015/16	2016/17	2017/18			2015/16	2016/17	2017/18
		Bir/hr	Bir/hr	Bir/hr		Birr	Bir/hr	Bir/hr	Bir/r
2	PPE-350x	343.48	457.15	466.0	CT-0025	4,364,500	390.0	509.00	529.9
8	NHE-265	390.58	409.01	566.0	CT-0017	4,009,472	404.0	534.40	667.8
12	KD-41E	488.30	760.00	841.0	CT-0021	899,007	528.0	760.80	863.0
17	CsE-1288	740.30	770.22	842.0	CT-0014	161,4102	856.0	801.60	1051
19	Ct-D4-SR	748.25	729.82	836.8	CT-0012	793,052	982.0	1148.8	1460

PPE.350x-Power plus Excavator, NHE-265-New Holland Excavator, KD-41E- Komatsu Dozer, CsE1288-Cass Excavator, Ct.D4-sr-Caterpillar Dozer

As can be seen in the Table 4.7 with appendixes I2e and Table 4.8 with appendix I2e below oil and lubrication consumption was analyzed for the selected farm machines. In the three consecutive year's taken actual and theoretical oil and lubrication consumption was considered and studied in WSSF.

As the results show in the Table 4.7 and Table 4.8 the actual oil and lubricant consumptions was much higher than the theoretical values in all years. This caused great loss of costs for the company, this could be that the organization follow systematic and planned maintenance program which was no failure analysis and use of the machines which go to breakdown maintenance frequently and higher losses of oil and lubricant due to leakages of the machinery.

These conditions caused the Company to loss more money during the mentioned years. In order to solve these problems WSSF should follow the proper Preventive Maintenance program rather than breakdown maintenance of machines to be more productive in the future time.

Table 4. 7: Theoretical and Actual Oil and Lub Cost/Hour in Birr for WT

Machinery Age	Current Type	Theoretical Oil&lub Consumption Rate /hr. in the service years			Plate N0	Machinery Purchase price	Actual Oil & Lub Consumption Rate/hr. in the service Years		
		2015/16	2016/17	2017/18			2015/16	2016/17	2017/18
		Bir/hr	Bir/hr	Bir/hr		Birr	Bir/hr	Bir/hr	Bir/hr
4	JD-5725	27.3	34.2	31.0	WT-0163	789,052	37.62	38.50	38.43
5	Bl-17716	25.65	28.21	31.36	WT-0180	2,068,993	25.69	28.52	33.30
5	CL-2254	109.7	109.7	120.7	WT-0087	1,822,922	115.2	117.3	120.98
11	S-130DT	53.7	47.02	51.73	WT-0078	449,037	58.65	48.45	54.67
15	MF4260	136.5	99.75	120.6	WT-0032	242,270	141.4	105.7	137.8

JD-Johndeer, BL-Bell, CL-Camico loader, S - Sami, MF-Massy Ferguson

Table 4. 8: Theoretical and Actual Oil-Lub Cost/Hour in Birr for CT

Current Age	Machinery Type	Theoretical Oil&lub Consumption Rate /hr. in the service years			Plate N0	Machinery Purchase price	Actual Oil & Lub Consumption Rate/hr. in the service Years		
		2015/16	2016/17	2017/18			2015/16	2016/17	2017/18
		Bir/h	Bir/h	Bir/h		Birr	Bir/h	Birr/h	Bir/h
2	PPE-350x	51.5	68.6	69.9	CT-0025	4,364,500	52.86	73.29	75.24
8	NHE-265	58.58	61.35	126.2	CT-0017	4,009,472	58.72	65.48	138.4
12	KD-41E	73.24	114.0	126.2	CT-0021	899,007	78.80	121.5	128.8
17	CsE-1288	111.0	115.5	126.3	CT-0014	161,4102	113.5	121.3	126.8
19	CtD4-SR	112.3	109.5	125.5	CT-0012	793,051	132.6	137.5	132.4

PPE.350x-Power plus Excavator, NHE-265-New Holland Excavator, KD-41E- Komatsu Dozer, DE-302Lcv-Daewoo Excavator, CsE1288-Cass Excavator, Ct.D4-sr-Caterpillar Dozer

The average actual total costs varied from the average theoretical total costs in season 2015/16 to 2016/17 for wheel tractor by 19%, while in the second season it was by 32%. Also it has been observed that the average actual costs and the average theoretical costs for crawler tractor were increased by 14.57% and 18.77% respectively in the second season compared to the first season. These may be attributed mainly to the bad record of data and poor system management.

4.9. Maintenance Management Performance Level Assessment

The process began with the analysis of the maintenance management in the sugar estate farm to measures the performance of maintenance management by evaluating the actions taken on the maintenance processes sick's to avoid failure occurrence and identifying the root cause of challenges.

As in the figure 4.10 machinery related information gathered on the average functional machinery process effectiveness in WSSF was 30.33%, which places the maintenance management system at poor performance. The suggested action for this level is to begin planning for preventive maintenance rather than corrective maintenance action on machineries considering the risks and consequences of the failures.

The number of Machine available is satisfactory, but the maintenance activities should be periodically monitored to ensure overall equipment effectiveness. The company also realized that many machines did not comply with the theoretical cycle time that had been set, because many unplanned breakdowns occurred during operating hours as in the figure 4.10. These unplanned breakdowns usually resulted from minor losses with minor maintenance activities conducted by the machanics.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions on Key Research Findings

An investigation in to the status of maintenance management system at Wonji-Shoa sugar estate revealed that their MMS needs attention especially on preventive maintenance rather than corrective maintenance in the maintenance and service department. In sugar estate most of the machineries have been subjected to a repeated maintenance and repair. The following were the key research findings of this study:

In the case studies there was no clear, well defined and documented departmental maintenance policy. There was some indication on plan of action on machinery maintenance but it was outward that the plan of action was not documented and well defined in form of a policy document.

The predominant maintenance strategy for machinery was corrective maintenance which based on emergency and priority with very limited preventive maintenance, where there was a maintenance plan, this was hardly observed to in the course of the year for which it's intended. This has resulted in a backlog of maintenance works.

No condition standards were set for the machinery maintenance therefore any clear performance indicators set from the outset to gauging effectiveness of the machinery maintenance strategies. Some machineries conditions are therefore left to deteriorate to very low standards as there are no guidelines or benchmarks for maintenance activities.

Annual maintenance works program have been adopted in maintenance management but its implementation was reported to be average due a lot of intervening factors. It also evident that no maintenance management manual where all information regarding maintenance of machinery and other facilities is recorded. From read-through records it was not possible to collate historical information of all maintenance activities relating to specific machinery.

The organization of maintenance in the FESD established a mix of both centralization and decentralization of their organization structure. It was evident that there was a shortage of qualified and experienced staff at the mechanic level when related to the demand of work in maintenance.

In the development of the human resource for maintenance departments was apparently neglected as the staffs was not trained further to upgrade or improves their skills. Staff at lower levels reported that they are not taken for refresher courses or trained in modern technologies of machinery maintenance.

The average actual total operating costs varied from the average theoretical total operating costs in season 2015/16 to 2016/17 for wheel tractor by 19%, while in the second season it was by 32%. Also it has been observed that the average actual costs and the average theoretical costs for crawler tractor were increased by 14.57% and 18.77% respectively in the second season compared to the first season. These may be attributed mainly to the bad record of data and poor system management.

An in-depth analysis, revealed that various shortcoming as compared to best practice maintenance bench mark criteria leading to an overall conclusion that the poor maintenance management system negative impacts on the machinery as maintenance activities were focused and efficiently implemented.

5.2. Recommendations

Maintenance managers at FESD to embrace proactively preventive maintenance tasks into their work order systems. The corrective maintenance approach or maintenance on crisis should be avoided

The factory should encourage its mechanics and operators to become familiar with the machineries they operate. Training should be provided for them to acquire the ability to detect machinery abnormalities and make improvement, the ability to understand machinery functions and mechanisms, the ability to detect causes of abnormality and damage.

As an integral part of their maintenance management system, the managers need to formulate and document their maintenance policy and strategic maintenance plan for effective and efficient machinery maintenance works.

Daily, weekly and monthly checklist should be available for every machine to be inspected by operators, mechanics and auto electricians. The equipment's should be kept clean as most of the abnormality developed due to dirty. The frequency of inspection should consider the equipment history as well as factors like status of the equipment.

Managers in FESD need to embrace the application of modern information technology in maintenance management by computerization of their maintenance records. Also in the modern times maintenance managers must invest in software that would improve efficiency of their maintenance management systems.

Machineries which beyond useful life should be disposed and replaced with new one following proper procedures. Old machineries resulted to high frequency of breakdown, high down time, high spare part cost, fuel cost and oil cost. Thus, WSSF should have machinery disposal and replacement police in order to maintain machineries in proper condition.

Wonji-Shoa sugar estate maintenance management system as an integral part of their operations that contributes to their success in meeting their strategic objectives. A deliberate and proactive effort must be taken to facilitate the maintenance work by enhancing manpower with appropriate skills, qualifications and experience to manage and execute maintenance work.

Spare parts should be managed well by classifying them as consumable, standard, and special spare part for every equipment to facilitate the ordering process. The development of effective and efficient maintenance planning and control system was one of the major inputs, which enables to forecast the spare parts requirement and deserves further attention.

The average actual total operating costs and average theoretical total operating costs increases from the season 2015/16 to 2016/17 for machinery from 19% to 32%. The study recommended that to reduce the operating cost by following proper maintenance management and using preventive maintenance rather than corrective maintenance system.

REFERENCES.

Amana W, (2010). Investigation into Effectiveness of Agricultural Machinery Maintenance Management, Unpublished MSc. Thesis Submitted to ASTU.

Antehun C. (2010). Productivity Improvement through Efficient Farm Machinery Maintenance Management. Thesis Submitted to ASTU.

Al-Turki, U. (2011). A framework for strategic planning in maintenance. Journal of Quality in Maintenance Engineering, 17(2), 150–162. Doi: 10.1108/13552511111134583

Anthony Kelly, (2006). Maintenance Systems and Documentation, Elsevier Ltd Amsterdam

ASAEB Standards, (2015). Capital recovery factors of agricultural machinery, st.joseph & Michigan. USA

Begg, D., Fisher, S., and Dornbusch, R., (1987). Estimating the real depreciation rate of farm machinery. Economics, 2nd ed Mc Qraw-Hill.

Bowers, W., 1992. Agricultural Machinery Management. Deere & company service. USA.

Campbell, J. D. (2016). Uptime, 3rd Edition. CRC Press.

Dhanpat Rai, (2004). Khanna, Industrial Engineering and management

Demis,A, Afwork,B.,Getachew,B., & Tesfaye,K. (2002). Training Manual. Ethiopian Society of Mechanical Engineers. ESME. Ethiopia.

Dhillon, (2002). Engineering maintenance: Modern approaches, CRC press LLC,

Dinesh Sheony and Bikash Bhadury, (2005). Maintenance Resource Management: Adapting MRP, Taylor and Frances Incs., USA.

Dunn, S. (2003). The fourth generation of maintenance. Retrieved from http://www. Plant maintenance. com/articles/4th_Generation_Maintenance.pdf

Edwards, W. Ayres G. and Boehlje, M. (2001). Estimating farm machinery costs. Iowa State University, extension service, machinery management series. Ames, Iowa .PP:1-11

Gifford R.C. Rijk A.G., (1980). Economic and Social Commission for Asia and the Pacific (ESCAP), Regional Network for Agricultural Machinery

Global Agricultural information network (GAIN) (2015), Ethiopia Aims to Become One of the World's Top 10 Sugar Producers Report Number, ET1532.

Goense, D,(1995) fundamental of farm mechanization system , lecture note, wagagen agricultural university, Netherlands.

Gulati. R, Smith R. (2009) Maintenance and Reliability Best Practices. [Electronic] New York: Industrial Press.

Herbaty, F. (1983), Cost-effective maintenance management: productivity improvement and downtime reduction, N.J: Noyes Publications, Park Ridge.

Higgins R. and Mobley, (2002), Maintenance engineering Hand book, 6th edition, Mc Graw Hill Companies.

Johnson I. (1979). Spare parts for agricultural machinery in developing countries. Keynote paper, FAO. Panel of experts on agricultural mechanization. Loton(U.K.), Nov. 29

Journal of Agricultural Technology, (2010), Vol. 6(4): 673-686 Available online http://www.ijat-rmutto.com.

Kastens, T., (1997). Farm machinery operation cost calculations. Kansas State University - Extension Service. MF-2244, File code: Farm Management 2 - 2.

Keith R. Mobley, (2008), Maintenance Engineering Handbook, 7th edition, New York, Mc Graw Hill.

Langemeier, L. N., and Taylor R. K. (1998). A look at machinery cost. Kansas State University,. Machinery and equipment 1- MF-842, file code: Farm Management 2-2.

Lee, R (1987). Building Maintenance Management Professional Books, Great Britain.

Niebel, Benjamin W. (1994). Engineering maintenance Management, 2nd Ed., Marcel Dekker Inc., http//www.maintenaceplant.com

Norm Dalsted, (2008), Agriculture and Business Management, Colorado State University.

Oakland, S.J. (1993). Total Quality Management. Second edition.

Parida. A (2006). Maintenance Performance Measurements (MPM); Issues and challenges, Journal of Quality in Maintenance Engineering Vol. 12 No.3,

Rathenshwar S, Dhaval D. S, Ashish M. Milesh H. S.(2013) ,Overall equipment efficiency(OEE) Calculation – Automation through Hardware & Software Development. Procedia Engineering 51 579 – 584.

Seeley I.H. (1976); Building Maintenance, Macmillan, London,

Siemens, J. C, and Bowers, W., (1999). Machinery management. Deere and Company, Litho – USA. 5th edition.

Stadnicka D, Antosz K, Ratnayake R.M.C. (2014), Development of an empirical formula for machine classification: Prioritization of maintenance tasks. Safety Science, 63: 34–41.

Tomlingson, P.D. Effective maintenance (1993), the key to profitability: a manager's guide to effective industrial maintenance management, Van Nostrand Reinhold, New York.

Tsang, A.H.C., Jardine, A.K.S., & Kolodny, H. (2002). Measuring maintenance performance: A holistic approach. International Journal of Operation & Production Management, 19(7), 691-715.

William Edwards (2009), Estimating Farm Machinery costs, IOWA University

William F. Lazarus, (2008), Estimating Farm Machinery Repair Costs, University of Minnesota,

APPENDIXES

Adama Science and Technology University.

School of Mechanical, Chemical and Material Engineering

Agricultural Machinery Engineering program.

APPENDIX A

Appendix a 1. Questionnaire for Maintenance Staffs

Dear participant, as part of my MSc study in Agricultural Machinery Engineering, I am undertaking a research study on the title, "Investigation in to the Status of the Maintenance Management System of Farm Machinery." The main purpose of this questionnaire is to collect data pertaining to farm machinery Wonji-Shewa sugar estate farm. The questionnaire would serve as a major input for a research conducted in pursue of academic purpose. Therefore, the respected respondents kindly requested to give us your genuine response to the questions included here below in the structured questionnaire. I would like to make sure that the response of the respondents is totally confidential/secured/. I would like to thank you in advance for your patience and cooperation.

Please put a mark ***(√)*** on the box provided, if you have comment please write up on the space provided.

Part I. General Information.

1. Name of the respondent……..2. Name of company……

3. Name of working department …….4. Working section/unit……

Part II. Employee Characteristics

1. Age of respondent ……..

2. Sex; Male, ☐ Female ☐

3. What is your maintenance working section?

Heavy equipment section	☐	state car section	☐
Wheel tractor section	☐	other section	☐

4. How long have you been in this maintenance/working section?

1-3 years	☐	10-13 years	☐
4-6 years	☐	13-16 years	☐
7-10 years	☐	16 & above years	☐

Part III. Maintenance Planning and schedule

1. Does a maintenance department have maintenance schedule?

Yes ☐ No ☐

If No, please specify a reason……

2. Commitment of management in maintenance job schedules to reduce the cost of maintenance?

Very Good ☐ Average/Fair ☐ Good ☐ Poor ☐

3. When the job is completed, the actual time, machinery downtime, and other information reported are

Very Good ☐ Average/Fair ☐ Good ☐ Poor ☐

4. The actual time compared to the estimates for monitoring Planning effectiveness is

Very Good ☐ Average/Fair ☐ Good ☐ Poor ☐

5. Planned work orders experiencing delays due to poor or incomplete plans are

Very Good ☐ Good ☐ Average/ Fair ☐ Poor ☐

6. Does the department have a well-defined and documented policy on the maintenance?

Yes ☐ No ☐

If Yes, how would you evaluate its implementation?

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

7. Does the department have a maintenance strategy?

Yes ☐ No ☐

If yes, what is the maintenance strategy?

Preventive maintenance ☐ Corrective maintenance ☐

Condition based maintenance ☐

Other (Please specify)……...

8. Does the department set PM program at which various machines should be maintained?

Yes ☐ No ☐

8a.If No, what challenges hinders this……

8b. If Yes, how regularly do you review/check and evaluate the above PM program?

Monthly ☐ Quarterly ☐ Annually ☐

Other (Please specify) ……

9. Does the departments prepare an annual maintenance work plane?

Yes ☐ No ☐

If Yes, how would you rate its implementation

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

Part IV. Maintenance Information

1. Does the department have a maintenance manual which outlines all information regarding maintenance of machinery and other facilities?

Yes ☐ No ☐

2. Does the department maintain an asset register of all machinery maintained?

Yes ☐ No ☐

3. If yes, which of the following information does it contains

machinery type, model & make ☐ Types of maintenance and Age ☐

Functions of machinery ☐ Replacement cost of maintenance ☐

Maintenance history-maintenance work done on it. ☐

Previous and current condition assessment reports ☐

4. Is the asset register updated regularly?

Yes ☐ No ☐

5. Do you have a computerized data base of maintenance records?

Yes ☐ No ☐

6. Do you have in place a computerized maintenance management system (CMMS)

Yes ☐ No ☐

7. If No, what is the challenges faced in developing a maintenance information system for the department……

Part ∇. Maintenance organization and training program

1. Does the department have a policy on the training of staff at all levels?

Yes ☐ No ☐

2. The frequency of formal maintenance training is provided to all maintenance workers is

Very Good ☐ Good ☐ Fair ☐ Poor ☐

3. The quality and skill level of the maintenance work force is

Very Good ☐ Good ☐ Average /Fair ☐ Poor ☐

4. Maintenance tools/equipment quality and quantity in the department is

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

5. Maintenance shop work area layouts

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

6. Availability of maintenance planners is

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

7. What is your evaluation of the sufficiency of the number of staff at the various levels given the needs of the department in relation to human capital? [Please tick as appropriate]

Level of staff	No of staff	Very Adequate	Adequate	Fairly Adequate	Insufficient
FESD Managers	1				
Middle level managers	3				
Technical staff/ supervisor	3				
Foremen	27				
Seiner Mechanic	31				
Junior Mechanic	66				
Assistant junior mechanic	56				
Total	187				

Part ∇I. Maintenance Implementation

1. The PM inspection/task checklists which are checked to ensure completeness is

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

2. The frequency of a PM inspection or task/service interval is

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

3. Does the department conduct condition assessment or physical inspections of machineries

Yes ☐ No ☐

4, The management gives attention to the maintenance department

Very Good ☐ Good ☐ Fair ☐ Poor ☐

5. In your evaluation how would you rate the sufficiency of funding received for maintenance works against the maintenance needs of agricultural machinery

Very Adequate ☐ Adequate ☐ Fairly Adequate ☐ Insufficient ☐

6. In your evaluation how would you rate the maintenance management system for procurement of materials and services of maintenance works?

Exceeds Expectations ☐ Meets Expectations ☐

Barely Meets Expectations ☐ below Expectations ☐

7. Lack of supply the spare parts.

Very Good ☐ Good ☐ Average/Fair ☐ Poor ☐

8. Briefly enumerate other challenges faced in implementation of maintenance works

…….

Please kindly check no points are escape

Thank you very much for your time!!

Appendix A 2. Employer's response for Questionnaire assessment

Sir N^{0}	Maintenance Management System	Current status and employer's response				
		Very good	good	Average /fair	poor	Total in number and percentage
1	Maintenance workshop facility	16	31	28	38	113
		14.2%	27.4%	24.8%	33.6%	100%
2	Availability of maintenance Planner	19	29	36	29	113
		16.8%	25.7%	31.9	25.7%	100%
3	Planning and scheduling implementation rats	25	31	46	11	113
		22.1%	27.4%	40.7%	9.7%	100%
4	Maintenance Information and work order	14	23	37	39	113
		12.4%	20.4%	37.7%	34.5%	100%
5	Manpower Training	_	30	27	56	113
		0%	26.5%	24%	49.5%	100%
6	Supply of spare part	26	11	25	51	113
		23%	9.7%	22,1%	45.2%	100%
7	Maintenance record and Documentation.	-	16	25	72	113
			14.2%	22.1%	63.7%	100%

Appendix A 3. Maintenance bench marks

Indicators	Implementation Goal (world class),	Implementation on Current situation (WSSF)
I. Maintenance organizations		
1.Maintenance organization chart	Current and complete	No chart
2.Job description available for	All maintenance staff	No clear job description
3. Maintenance workshop area layout	perfect	Poor
4.Maintenance tools quality and quantity	perfect	Poor quality and quantity
5.Maintenance organizational effort	Excellent	Poor
6.Maintenance organizational assignment	Responsibility fully documented	Not as required
II.Training program		
1. Maintenance craft training	Training is tied to pay	No scheduled training
2.Maintenance training frequency	Less one year (12-18 months)	Irregular and for from standard
3.Formate of maintenance training	Training is mix of class and lab exercise	Not applicable since no training
4.quality and skill level of maintenance workforce and supervisory group	perfect	Poor
III. Preventive maintenance		
1. PM includes:	-Lubrication check lists -Person specifically assigned to the PM program -Detailed inspection lists PM diagnostics	it is not possible to quantify PM works
2.What % of PM inspection/task checklists are Checked for completeness	90%, 75-90%, at least 60-75%	Difficult to quantify
3. What determines the frequency of PM inspection or tasks/service intervals	Condition based, run time and fixed calendar	Run time for lub; Frequency of break down for over hauling

IV Maintenance planning & scheduling		
1.what % of work non-emergency are completed monthly report	More than 90%,75-90%, 60-75%	Work is emergency
2.what % planned work delay due to incomplete plan	Less than 10%, at most 10-20%	Almost all
3.What % of the actual compared to the estimates for monitoring planning effectiveness	More than 90%, 75-90%, 60-75%	No such monitoring practices
V. Maintenance job scheduled issued	Weekly or bi-weekly	Not regular
VI. Maintenance reporting		
1. What % of the time are maintenance reports distributed on a timely basis to the appropriate Personnel	More than 90%, 75-90%, 60-75%	Not specified
2. Are the following reports produced	-MTTR and MTBF for vehicles	No

APPEDIX A 4. Structured Interview for Maintenance Staffs

Date_____Sex _____Age_____.Department____

Job-title_____Workexperience_____Qualification_____.

1. Is the maintenance work shop suitable for maintenance work? If no, why?

2. Is there over load work of machineries? If yes, what is the influence on machineries?

3. Do you keep a record of all your daily activities? Are these records stored also as computer records?

4. Do you think that preventive maintenance increases the life of the machines? If yes, how?

5. Has the situation improved or worsened in the last five years? If it has worsened what in your opinion is impeding effective maintenance of machineries.

6. What in your opinion would you rate as the greatest challenge in maintaining the machinery?

7. Are there machines that are out of work, due to other than spare part problem? If yes, what are the causes?

8. Would you say that you have sufficient training and skills to execute your work/ if no what way can this be improved?

9. In your opinion the departmental maintenance processes and procedures effective in addressing the maintenance needs of the agricultural machinery?

10. Does the department have acceptable levels of materials to adequately support maintenance and repair works?

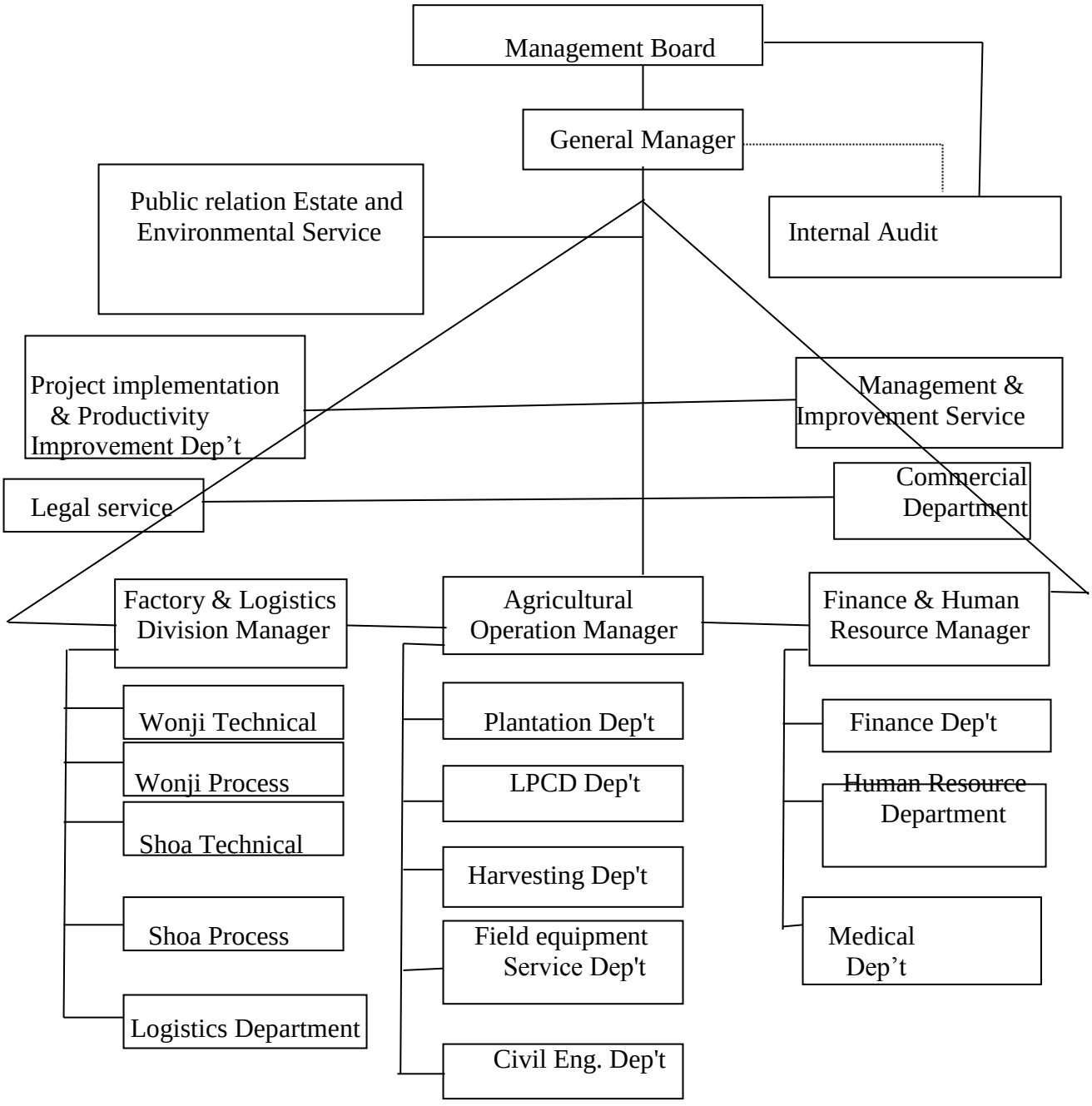
11. Is there on job training related to your works? If yes, where, at what frequency?

12. Any suggestions on how maintenance management can be improved given challenges faced

APPENDIX B

Appendix B. The Existing Organizational Chart of Wonji-Shoa Suger Estate Farm

Company Name: WONJI-SHOA SUGAR FACTORY	
Issue No: Title: Organizational structure	Document No. WI/WSSF/006/001



APPENDIX C

Appendix c 1: Types of Wheel Tractors in Work

Wheel Tractor Model	Purchas Year	Nº in Work	Age(years)	Delivered Hp	Useful life	Initial Price	Utilized department
MF440-4WD	2007	6	11	80	12	230,216.7	LPCD
MF5475-4WD	2014	5	4	160	12	1,753,040	LPCD
MF465-4WD	2007	2	11	115	12	313,800.87	LPCD
KAT. 1804	2015	15	3	180	12	2,177,200.41	Hrvt
YTO 1804	2015	14	3	180	12	2,176,284.28	Hrvt
Bell17716AF	2013	21	5	180	12	2,068,993.38	Hrvt
URSUSE 20014A	2016	1	2	200	12	186,200.00	Hrvt
URSUSE 25014A	2017	5	1	250	12		Hrvt
John. Deere 5725	2014	9	4	80	12	789051.88	LPCD
John. Deere 9410	2014	4	4	410	12	2,476,284.28	LPCD
John. Deere 9330	2012	3	6	330	12		LPCD
John. Deere 2254	2017	6	1	225	12		LPCD
Same 130DT	2008	4	10	130	12	449036.73	LPCD
Cam. Art. L 345B	2014	3	4	345	12	4,852,420.46	LPCD
CHN.NH TD80	2013	13	5	80		502737.61	Fabrica
Total wheel tractors in work = 111							

Appendix c 2: Types of Crawler Tractors in Work

Crawler Tractor Model	Purchas year	Initial Price	Nº off in Work	Age(Year)	Useful life	Deliver Hp	Utilized Department
PPE, 350E-X	2015		2	3	16	186	Civil
PPD, D85E	2016	2,267,800	1	2	16	200	Civil
NHE, E265B	2010	4,009,472.22	1	8	16	143	Civil
NHD, D-180	2001	1,564,523.6	1	11	16	180	Civil
Daewoo Exc.250Lcv	2005	970,847.91	1	13	16	165	Civil
Cat. DR XL	2013	5,608,945.88	2	5	16	160	Civil
Cat .D4E-SR	2008		3	10	16	180	Civil
Dr. Dozer Td-25m	2017		1	1	16	210	Civil
Komatsu. D41E	2006	899,007.55	1	12	16	110	Civil
Komatsu. D85E	2008	1,557,469.6	2	10	16	210	Civil
Total crawler tractors in work in %							13

Appendix c 3: Types of wheel tractors out work

Wheel Tractor Model	Purchas year	N^{0} out of work	Age (year)	Deliver Hp	Initial Price	Status
M F 398-4WD	2007	8	11	80	134,875.78	to be dispose off
MF465-4WD	2007	1	11	115	313,800.87	to be dispose off
MF440-4WD	2005	13	11	80	196,352.31	to be dispose off
FNH80-66 S	2003	8	15	80	300383.42	to be dispose off
FNH80-66 S	2007	4	11	110	300383.42	to be dispose off
MF4260-4WD	2003	8	15	104	242,269.94	to be dispose off
MF5365	2005	3	13	115	351,079.11	to be dispose off
MF5475-4WD	2014	1	4	80	1,753,040.04	to be dispose off
MF660-4WD	2006	4	12	150	776043.32	to be dispose off
Bell1716AF	2003	5	5	180	2,068,993.38	Need spare parts
Belarus 920/Ntap/	2009	1	9	80	431,980.61	to be dispose off
Same 130DT	2008	18	10	130	451,241.68	to be dispose off
URSUSE 20014A	2016	4	2	200	186,200.00	Engine failure
John. Deere 5725	2014	1	4	80	789051.88	Engine failure
John. Deere 9410R	2014	2	4	410	2,476,284.28	Engine failure
Total wheel tractors out of work = 78						

Appendix c 4: Types of Crawler Tractors out Work

Crawler tractor Model	Purchas year	N^{0} out of work	Initial Price	Age (year)	Deliver Hp	Useful life	Status
Cat D6K	2010	2	4726548.07	8	125	16	engine failure
Cat .D4E-SR	2008	2		10	180	16	engine failure
PP350E-X	2015	1		3	186	16	engine failure
Komatsu.D41E	2006	2	899,007.55	12	110	16	To be dispose off
Komatsu D85E	2008	2	1,557,469.6	10	210	16	To be dispose off
Dragline 305B	1995	1	1,557,469.6	23	78	16	To be dispose off
Total machinery out of work = 9							

Appendix c 5: Machineries under Major Repair and Waiting for Spare Parts




Appendix c 6: Machinery out of Work that Needs to be Disposed




APPENDIX D: Farm machinery grouping according to their ages

Appendix D 1, Wheel Tractors Age Grouping

Wheel Tractor			Age group (years)		
Type	Make	Total No	1-5	6-10	>10
Massey Ferguson Tractor	England	51	6	-	45
FIAT New Holland Tractor	Italy	12	-	-	12
Belarus Tractor	Ethiopia	1	-	1	
John Deer Tractor	American	25	22	3	-
Same Tractor	Italy	22	-	22	-
YTO Tractor	China	14	14	-	-
KAT Tractor	China	15	15	-	-
BELL Tractor	south Africa	26	26	-	-
CNH New Holland Tractor	Italy	13	13	-	-
Steyr Tractor		2			
URSUS Tractor	Poland	10	10	-	-

Appendix D 2. Crawler Tractors Age Grouping

Crawler Tractor			Age Group (Years)		
Type	Make	Total No	1-5	6-10	>10
Komatsu	Japan	7	-	4	3
Dragline	England	1	-	-	-
Case Excavator	France		-	-	1
Daewoo Excac.	Korea	1			
New Holland Excavator	Italy	1	-	1	-
New Holland Dozer	Italy	1	-	-	1
Caterpillar	America	9	2	7	-
Power Plus Dozer	China				
Power Plus Excavator	China	2	2	-	-

APPENDIX-E

Appendix E 1. The Total Numbers of Maintenance Personnel in the FESD.

S/N^{0}	Job Title	Staff N^{0}	Salary Grade	Education background.
1	FESD Team Leader	1	21	Agriculture Mechanization
2	Senior Automotive Engineer	4	18	Automotive Technology
3	Electrical Engineer	1	17	Automotive Technology
4	FESD Planning Expert	1	16	Construction Technology
5	Junior Automotive Engineer	2	14	Automotive Technology
6	Lead Auto Mechanic	25	13	Automotive Technology
7	Lead Auto Electrician	2	13	Automotive Technology
8	Auto Mechanic IV	28	11	Automotive Technology
9	Auto Mechanic III	42	10	Automotive Technology
10	Auto Mechanic II	40	9	Automotive Engine Servicing
11	Auto Mechanic I	20	9	Automotive Technology
12	Junior Administration Expert	2	10	Business Management
13	Dry Loading Driver IV	8	10	Grade 12
14	Secretary I	1	10	Business Management
15	Auto Electrician IV	3	11	Automotive Electricity
16	Auto Electrician III	2	10	Automotive Servicing Operations
17	Auto Electrician II	3	9	Automotive Technology
18	Welder III	12	10	Metal Engineering Technology
19	Welder II	11	9	Metal Engineering Production
20	Filed Try Maintenance	18	9	Automotive Technology
21	FESD Clerk II	3	8	Metal Engineering Production
22	Junior Auto Electrician	7	8	Grade 12 /Preparatory
23	Assistant Auto Mechanic	9	6	Automotive Engine Servicing
24	Junior Construction Mechanic	3	6	Grade 5-9
25	Junior Construction Electrician	3	6	Grade 5-9
26	Junior Tractor Electrician	9	6	Automotive Engine Servicing
27	Junior Tractor Mechanic	31	6	Automotive Engine Servicing
28	Oil & Lubricant Attendant	2	5	Grade 5-9
29	Laborer	7	2	Grade 5-9
30	Cleaner	2	1	Grade 5-9
	Total	302		

Appendix E 2. The Total Numbers of Workers in the LPCT

No	Job title	Staff N^{0}	Salary Grade	Education background
1	LPCD Team Leader	1	21	BSC. Degree Agricultural Engineering
2	LPCD Supervisor	2	16	Diploma Agricultural Engineering
3	Assistant Supervisor	2	14	BSC. Degree Agricultural Engineering
3	Land Preparation Foreman	3	13	BSC. Degree Agricultural Engineering
4	Heavy Machine Operator IV	1	11	Grade 8
5	Heavy Machine Operator IV	2	11	Level III Automotive Electrical
6	Heavy Machine Operator IV	1	11	Grade 4
7	Heavy Machine Operator IV	4	11	Level IV Automotive Servicing
8	Heavy Machine Operator III	2	10	Grade 4
9	Heavy Machine Operator III	2	10	Grade 10
10	Heavy Machine Operator III	2	10	Level II Automotive engine servicing
11	Heavy Machine Operator III	1	10	Level I Automotive Engine Servicing
12	Heavy Machine Operator III	1	10	Diploma Auto Mechanics Technician
13	Heavy Machine Operator III	1	10	Level III Automotive Servicing
14	Heavy Machine Operator II	5	9	Grade 12
15	Heavy Machine Operator II	2	9	Grade 9
16	Heavy Machine Operator II	1	9	Level II Automotive Engine Servicing
17	Heavy Machine Operator II	1	9	Grade 7
18	Heavy Machine Operator II	6	9	Grade 10
19	Bus Driver III/Isuzu/	1	9	10+1 Auto Mechanics Technician
20	Heavy Machine Operator II	1	9	Grade 12 Wood Work
23	Bus Driver III	1	9	Grade 10
24	Heavy Machine Operator II	2	9	Level IV Automotive Servicing
25	Heavy Machine Operator II	4	9	Level II Automotive Engine Servicing
26	Heavy Machine Operator II	1	9	Grade 8
27	Heavy Machine Operator II	1	9	Level III Industrial Machines
28	Heavy Machine Operator II	1	9	Level II Sugar Crop Production
29	Land Preparation Clerk II	3	8	Level IV Accounting
30	Tillage Field Co-Ordentor	1	7	Level II Automotive Engine Servicing
31	LPCD Field Worker	4	2	Grade 10
34	Cleaner	2	1	Grade 6
Total		62		

APPINDEX F

Appendix F 1. Annual Performance Plan Campaign 2016/17

N0	Target Set For	Total Annual Pl	Annual Performance Plan											
			July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
	A, Heavy duty Equipment Section													
1	overhaul maintenance	29	9	9	11	0	0	0	0	0	0	0	0	0
2	planned maintenance	508	37	37	38	44	44	44	44	44	44	44	44	44
3	Unplanned maintenance	445	16	16	17	44	44	44	44	44	44	44	44	44
	B, Wheel Tractor Section													
1	overhaul maintenance	31	7	7	9	8	0	0	0	0	0	0	0	0
2	planned maintenance	704	58	59	58	59	58	59	58	59	59	59	59	59
3	unplanned maintenance	810	67	68	67	68	67	68	68	67	68	68	67	67
4	Implements	466	10	10	10	40	46	50	50	50	50	50	50	50
	C, Implement													
1	overhaul maintenance	59	12	12	17	18	0	0	0	0	0	0	0	0
2	Partial Overhaul	108	9	9	9	9	9	9	9	9	9	9	9	9
3	planned maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix F 2. Annual Planned Maintenance 2017/18

Target Set For	Actual m/c	Pm	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
wheel Tractor	34	I	16	16	16	64	64	64	64	64	64	64	64	64
		S	8	8	8	32	32	32	32	32	32	32	32	32
		PO	8	8	6									
		CO	2	2	2									
		CM	5	5	5	14	14	14	14	14	14	14	14	14
		L	2	2	2	8	8	8	8	8	8	8	8	8
		M	2	2	2	4	4	4	4	4	4	4	4	4
		H	1	1	1	2	2	2	2	2	2	2	2	2
Crawler Tractor	16	I	6	6	6	32	32	32	32	32	32	32	32	32
		S	3	3	3	16	16		16	16	16	16	16	16
		PO	3	3	3									
		CO	2	1	1									
		CM	12	12	12	30	30	30	30	30	30	30	30	30
		L	8	8	8	20	20	20	20	20	20	20	20	20
		M	3	3	3	6	6	6	6	6	6	6	6	6
		H	1	1	1	4	4	4	4	4	4	4	4	4
Implements	27	I	6	6	5	28	56	56	56	32	32	20	12	0
		S	6	6	5	7	14	14	14	8	8	5	3	0
		PO	3	3	4									
		CO												
		CM				30	30	30	30	30	30	30	30	30
		L				20	20	20	20	20	20	20	20	20
		M				8	8	8	8	8	8	8	8	8
		H				2	2	2	2	2	2	2	2	2

APPENDIX G: Recommended maintenance check list formats for FESD

(Antehun, 2010).

Year _____

Appendix G 1. Planning and Inspection Office

Month _____

Date	Name of employ	Number of job order records	Number of Executions records	Remark

Prepared by ____ Checked by _____ Approved by _____

Appendix G 2. Daily Tire and Tube Repair Consumption Follow Up Check List

A-New tire Replacement B- New tube replacement C– Tube repair (plastering)

Date	Machine No	Repaired/Replaced Parts in Size	Quantity		Manufacturing Tire No.		Hours or KM
			Tire	Tube	New	Old	Traveled

Appendix G 3. Machinery History

Type of vehicle _____ Plate No._____

Model No. _____ Engine No._____ Chassis No._____

Date	Time		Spare part used			KM/ hr Reading	Mechanics Name
	Start	End	Description	Unit Price	Work performed		

Transcribed by _____ Sign._____

APPENDIX-H: The Recommended Maintenance Check Lists Formats

Appendix H 1. Maintenance Work Order Sheet

Maintenance section_____Tasks to be executed (maintenance stage) _____

Planned week_____ Order number_____

No.	Mechanic	Checked parts	Job start		Job Completion		Actual man hour		Spare parts replaced or other		
			Date	Hr	Date	Hr	Time	Cost	Part name	Qt	Cost
1											
2											
Total											

Prepared by Checked by Approved by

Maintenance planner Maintenance foreman Maintenance supervisor

Appendix H 2. Machine Maintenance History Record Sheet

Machine name_____

Manufacturer_____Address_____phone_____Fax_____

Date	Work order	Maintenance type	Cause	Man hour	Part replaced		Maintenance cost
					Name	Qt	

Appendix H 3. Breakdown Request Sheet

Maintenance section_____ Order date_____

No.	Machine Name	Present condition and status	Remark
1			
2			

Prepared by Checked by Approved by

Field operation foreman maintenance foreman Maintenance supervisor

Appendix H 4. Report Sheet for Backlog in Progress and Scrapped Machines

Section_____ Backlog_____ In progress _____Order date_____

Date _____

Machinery Under Preventive maintenance					Machinery Under Breakdown maintenance					Machinery Scrapped	
Name	Work order No.	Cause of in progress/backlog		Down time	Name	Work order No.	Cause of in progress/backlog		Down time	Name	Cause of scrapped
		In progress	Backlog				In Progress	Backlog			

Prepared by maintenance foreman Approved by maintenance supervisor

Appendix H 5. Weekly Maintenance Report Sheet

Section_____ Week_____ Date_____

No.	Work order No.	Machine name	Type of maintenance	Date of completion	Down time	Changed spare parts		Mechanic Id No.	Type of problem during inspection
						Name	Qt		
1									
2									
3									

Prepared by maintenance planner Checked by maintenance supervisor

Approved by maintenance manager

Appendix I 1. Standards of Accumulated Repair and Maintenance Costs

Table 3. Accumulated repair costs as a percent of new list price.

Type of Machinery	Accumulated hours									
	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Two-wheel drive tractor	1%	3%	6%	11%	18%	25%	34%	45%	57%	70%
Four-wheel drive tractor	0%	1%	3%	5%	8%	11%	15%	19%	24%	30%

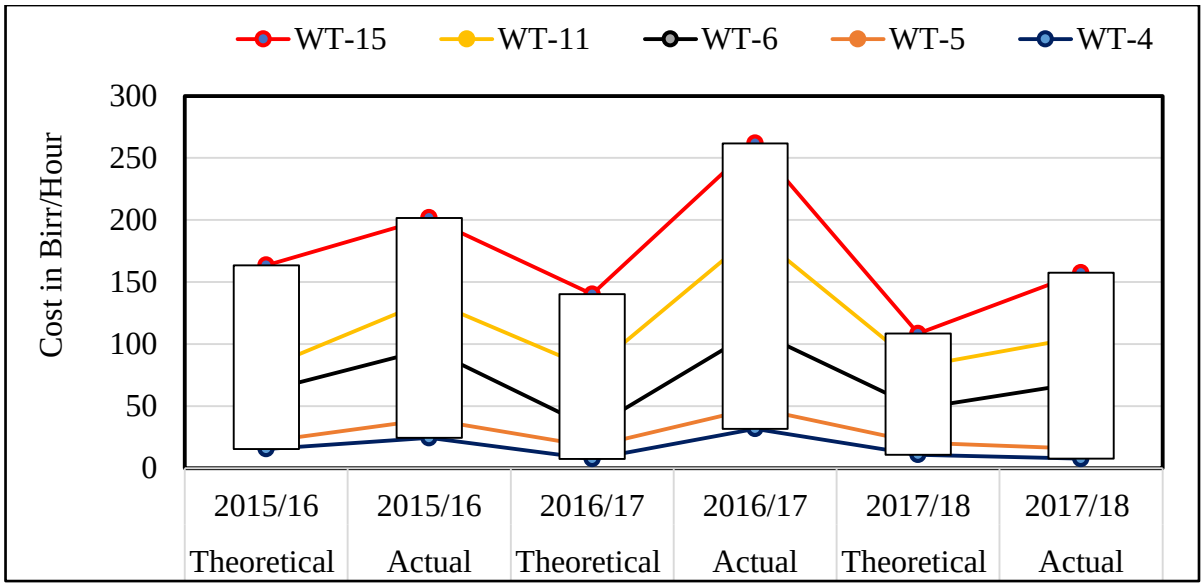
Table 1a. Remaining salvage value as percent of new list price.

	30-79 hp Tractor			80-149 hp Tractor			150+ hp Tractor			Combine, Forage Harvestor		
Annual Hours	200	400	600	200	400	600	200	400	600	100	300	500
Age												
1	65%	60%	56%	69%	68%	68%	69%	67%	66%	79%	69%	63%
2	59%	54%	50%	62%	62%	61%	61%	59%	58%	67%	58%	52%
3	54%	49%	46%	57%	57%	56%	55%	54%	52%	59%	50%	45%
4	51%	46%	43%	53%	53%	52%	51%	49%	48%	52%	44%	39%
5	48%	43%	40%	50%	49%	49%	47%	45%	44%	47%	39%	34%
6	45%	40%	37%	47%	46%	46%	43%	42%	41%	42%	35%	30%
7	42%	38%	35%	44%	44%	43%	40%	39%	38%	38%	31%	27%
8	40%	36%	33%	42%	41%	41%	38%	36%	35%	35%	28%	24%
9	38%	34%	31%	40%	39%	39%	35%	34%	33%	31%	25%	21%
10	36%	32%	30%	38%	37%	37%	33%	32%	31%	28%	23%	19%
11	35%	31%	28%	36%	35%	35%	31%	30%	29%	26%	20%	17%
12	33%	29%	27%	34%	34%	33%	29%	28%	27%	23%	18%	15%
13	32%	28%	25%	33%	32%	32%	27%	26%	25%	21%	16%	13%
14	30%	27%	24%	31%	31%	30%	25%	24%	24%	19%	14%	12%
15	29%	25%	23%	30%	29%	29%	24%	23%	22%	17%	13%	10%
16	28%	24%	22%	28%	28%	27%	22%	21%	21%	16%	11%	9%
17	26%	23%	21%	27%	27%	26%	21%	20%	19%	14%	10%	8%
18	25%	22%	20%	26%	25%	25%	20%	19%	18%	13%	9%	7%
19	24%	21%	19%	25%	24%	24%	19%	18%	17%	11%	8%	6%
20	23%	20%	18%	24%	23%	23%	17%	17%	16%	10%	7%	5%

Source: American Society of Agricultural Engineers (ASAE, 1996)

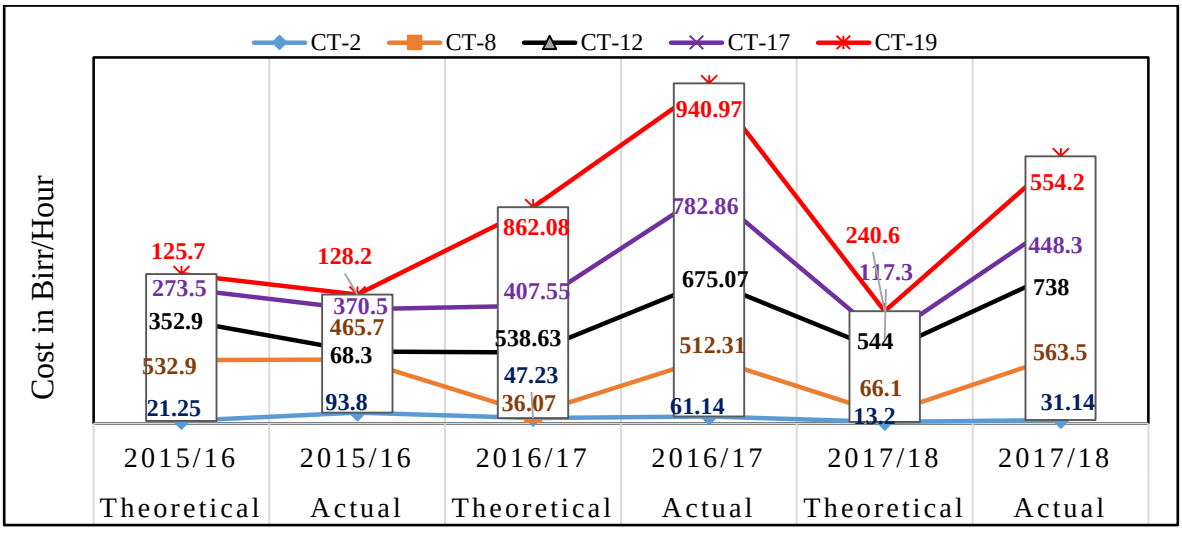
Appendix I 2: Operating Cost of Machinery

Appendix I 2a. Accumulated Theoretical and Actual Maintenance Cost/hour for WT



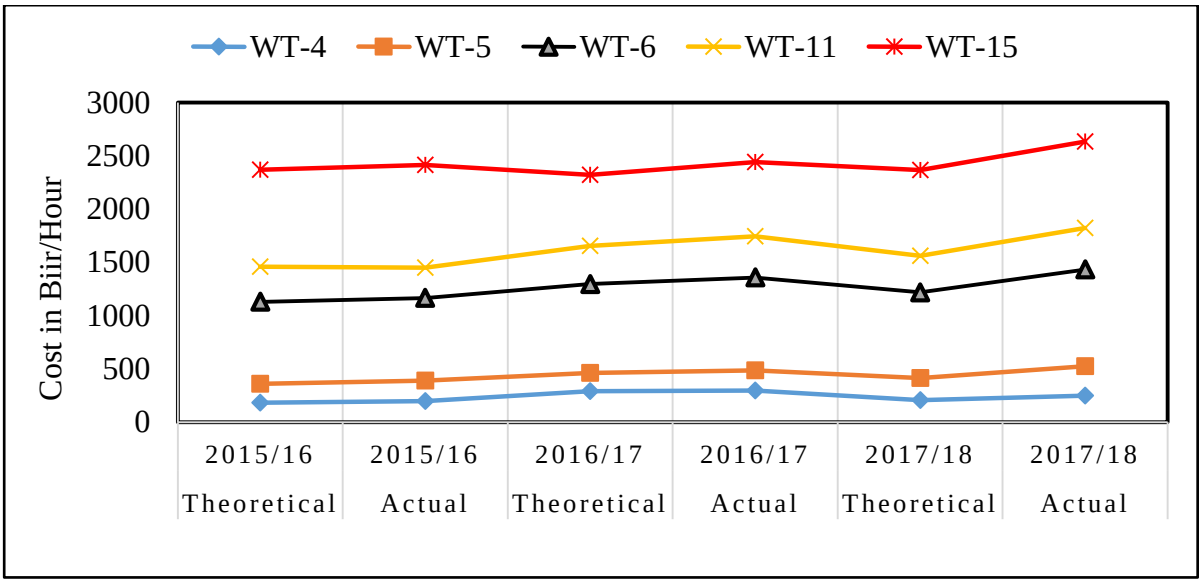
WT-4= wheal tractor at age 4, WT-5= wheal tractor at age 5, WT-6= wheal tractor at age 6, WT-11= wheal tractor at age 11, WT-15= wheal tractor at age 15.

Appendix I 2b.Accumulated Theoretical and Actual Maintenance Cost/Hour for CT



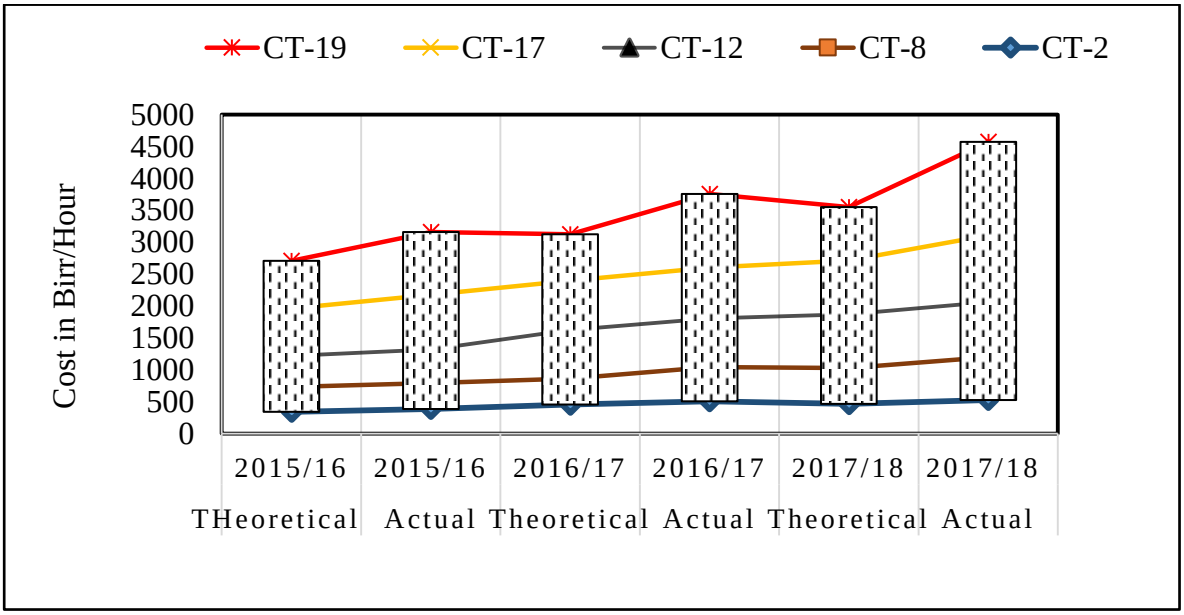
CT-2=Crawler tractor at age 2, CT=8 Crawler tractor at age 8, CT-12 Crawler tractor at age 12, CT= Crawler tractor at age 17, CT= Crawler tractor at age 19.

Appendix I2c .Accumulated Theoretical and Actual Fuel Cost/Hour for WT per Model



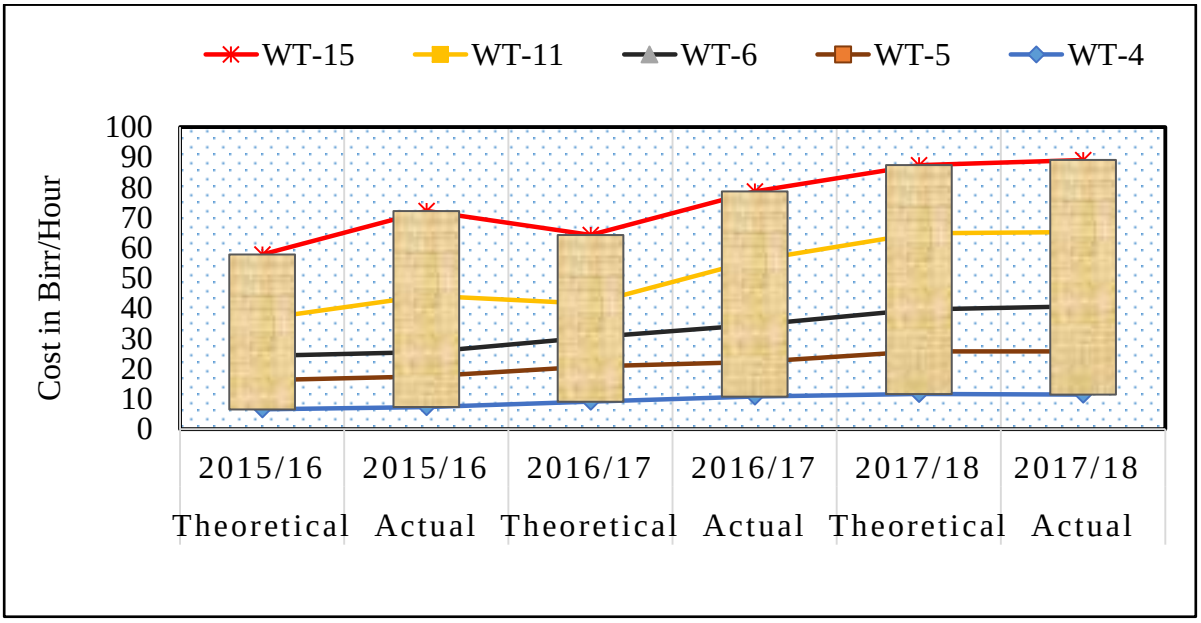
WT-4, wheel tractor at age 4, WT-5, wheel tractor at age 5, WT-6 wheel tractor at age 6, WT-11 wheel tractor at age 11, WT-15 wheel tractor at age 15.

Appendix I2d. Accumulated Theoretical and Actual Fuel Cost/Hour for CT



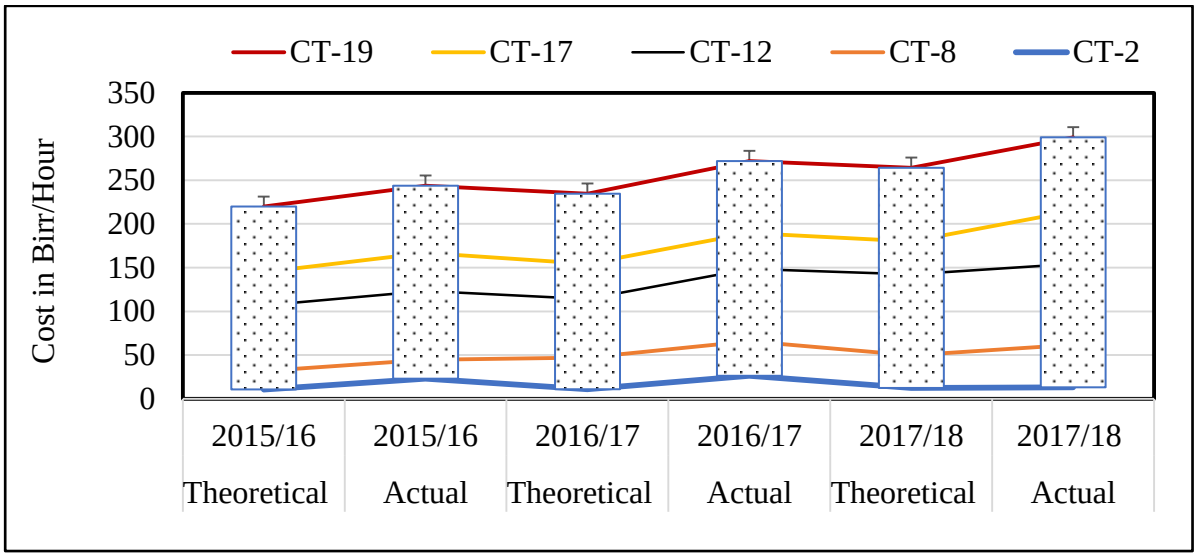
CT-2=Crawler tractor at age 2, CT=8 Crawler tractor at age 8, CT-12 Crawler tractor at age 12, CT= Crawler tractor at age 17, CT= Crawler tractor at age 19.

Appendix I2e.Accumulated Theoretical and Actual Oil &Lub Cost/Hour for WT



WT-4, wheel tractor at age 4, WT-5, wheel tractor at age 5, WT-6 wheel tractor at age 6, WT-11 wheel tractor at age 11, WT-15 wheel tractor at age 15

Appendix I2f. Accumulated Theoretical and Actual Oil &Lub Cost/Hour for CT



CT-2=Crawler tractor at age 2, CT=8 Crawler tractor at age 8, CT-12 Crawler tractor at age 12, CT= Crawler tractor at age 17, CT= Crawler tractor at age 19.